70APB19
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MINIGUN RESEARCH AND DEVELOPMENT PROGRAM

FINAL REPORT

AIRCRAFT EQUIPMENT DIVISION
GENERAL ELECTRIC
BURLINGTON, VERMONT

299

April 1970

SUBJECT: FINAL REPORT, R&D CONTRACT DAAF01-68-C-0060

This document is a final report for Scope Items 1 through 5 of subject contract, with one exception. When the final report is issued for the Design Studies, Scope Item 6, it will contain a section describing the work performed to incorporate timing features in the minigun clutch (Scope Item 2).

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MINIGUN RESEARCH AND DEVELOPMENT PROGRAM FINAL REPORT

By

Eugene B. Raymond

David R. Skinner

Henry R. White

Gerard J. Desany

Charles D. Rosier

Prepared For: U. S. Army Weapons Command
Rock Island, Illinois 61201

Prepared by: General Electric Company
Aircraft Equipment Division
Burlington, Vermont 05401

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ABSTRACT

This report describes the design, development, and testing of a new minigun bolt, clutch, side stripping feeder, guide bar (including tolerance studies), and armament pod for the XM-18.

The new bolt functions independently of any external cam, other than the main housing cam, and is completely interchangeable in all existing systems. Other advantages include reduced cost, longer life, and greater reliability.

The new solenoid operated clutch is located in the aft end of the gun and, therefore, does not interfere with the feed systems of the numerous minigun applications. The clutch stops the feed system at the end of a burst, but allows the gun to rotate and clear. A large savings is realized because no live ammunition is dumped during clearing.

The new delinking feeder sidestrips, rather than endstrips. It has fewer parts and is more durable, thereby reducing the cost and increasing the life of the feeder.

Tolerance studies of the guide bar interfacing with gun and feeder, high-speed films of round handoff from feeder to gun, and evaluations of various guide bar concepts were performed in an attempt to design a new guide bar which would decrease the gun's dependency on feeder timing and increase its tolerance to damaged ammunition. Conclusions and recommendations based on the studies, films, and evaluations are also included.

The new feed and storage system for the minigun pod incorporates a storage drum similar to the MXU 470 Minigun Module with a new feeder design that has fewer parts and is more durable. The combination of these new features more than doubles the reliability of the pod.

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SECTION I

MINIGUN BOLTS, SCOPE ITEM 1

A. INTRODUCTION

Scope Item 1 of this contract specified a new bolt design that will be fully interchangeable with all existing guns and systems. The bolt will be self-operating and independent of cams external to the bolt other than the main gun housing cam. Other desirable features would be lower manufacturing cost, longer life, and greater reliability than the present design. A design requiring a minimum of maintenance with less dependence on lubrication when resetting the firing pin was also desired. The design criteria attained in the final configuration exceed all initial development expectations.

B. DESCRIPTION OF TANGLESS BOLTS

The bolt design finally accepted is commonly referred to as a two-pin, self-actuating bolt. This design surpasses all original estimates of life expectancy and operational characteristics. There are only seven parts in this design, making greater reliability and greater ease in assembly possible. Figures 11, 12, and 13 show the bolt assembly.

As the name "self-actuating" implies, both triggering and resetting are performed as the bolt head locks and unlocks. Only the linear action of the gun housing cam is required to actuate the firing pin. Triggering is controlled by the "L" slot located in the bolt head. Resetting is performed by a triangular camming surface in the aft portion of the bolt body.

The operating cycle is initiated as the rotor turns, feeding the bolt assembly forward in reaction to the housing cam. The bolt head turns into lock and makes contact with the barrel face. The aft pin located in the bolt body prevents the firing pin from rotating with the bolt head. The "L" slot rotates relative to the forward cross pin located in the firing pin. Bolt head rotation continues until the forward cross pin rounds the "L" slot corner. The firing pin is then aligned to move forward in the longitudinal slot and is accelerated by the firing pin spring to indent the primer of the fully chambered round.

After dwell, the gun housing cam interacts with the rotor rotation to pull the bolt body aft to rotate the bolt head out of lock. This action rotates the firing pin and retracts it from the primer. Firing pin reset occurs when the forward cross pin reacts with the cross slot in the bolt head. During the last unlocking action of the bolt head, the aft cross pin interacting with the bolt body cams the firing pin in a clockwise rotation to its reset position. The two cross pins then transmit the extract loads. This cycle is represented in Figure 14.

This bolt design eliminated the need for the firing pin camming surface to be cut into the gun rotor and maintained at depot level. The new design also has a longer bolt body, providing more control of the bolt assembly as it moves forward in the rotor trackways. Primer indents are more nearly central due to increased support in the trackways. Wear of the removable tracks is reduced, increasing their life. Since the bolt head is firmly affixed to the assembly by the forward cross pin, it is impossible for a bolt head separation from the bolt body to occur, thereby a possible source of gun stoppage is eliminated. Spring stress is reduced in this design by increasing the coil diameter of the spring. Life expectancy of the spring is 250,000 rounds. The life expectancy of the bolt assembly is not known as five of the six original test bolts have been tested for over 300,000 rounds and remain operational. Only the forward cross pin and springs have been replaced. The new bolts functioned well at all rates from 750 to 6500 spm during tests.

All testing analyses and tolerance studies show this bolt to be a superior product. This design is expected to far exceed the present standard of reliability and part longevity at a significantly reduced cost.

C. DEVELOPMENT

Several designs were studied in the initial development state of a bolt mechanism which would function independent of the gun rotor. After an extensive evaluation of operating characteristics, reliability, producibility, and cost, the two-pin design was decided upon as the best approach. Work was then initiated on a set of prototypes. Concurrent work was done on tolerance and timing studies.

Particular effort was given to the firing pin spring to decrease the working stress necessary for the spring to deliver enough energy to insure primer firing, while keeping spring stresses as low as possible. A computer program was written to determine the parameters for an optimal spring. This program made is possible to analyze many different spring combinations and pick the best one for the new bolt. The program was also used to determine theoretical values for firing pin velocity, acceleration, and fall time - thereby, greatly increasing new design comprehension. The computer program and a print out of the present spring are included in Figures 20 and 21. The values of energy in this program are higher than actual values because they are theoretical values - the effects of friction were neglected. However, frictional losses will be a constant; therefore, the optimal theoretical spring will also be the optimal actual spring.

1. Testing

When the calculations and tolerance studies were complete, certain changes were made on the prototypes. They were then assembled and test fired. The testing revealed misfire occurance at both high and low rates. An investigation showed that under certain conditions firing pin protrusion was insufficient to fire the round. Corrective action involved making new pins with an additional 0.070 inch on the forward end.

Further testing indicated the misfire percentage had been reduced, but a very low (1 in 2000 rounds) percentage of misfires still existed. Further investigation of these persistent misfires indicated the aft pin might be rotating out of its proper firing position. To eliminate this possibility, a set of bolts was modified with a special cantilever spring arrangement (see Figure 15). This spring, located on the underside of the bolt, applied a force to the aft pin which returned it to its proper position. Resumed testing showed this configuration reduced misfire occurance, but did not eliminate it. A more detailed test was evolved to eliminate certain variables and determine the basic problem.

Velocity screens were employed in an effort to determine which bolt(s) misfired in a burst. With misfires occurring so infrequently, this test arrangement was needed to determine if one bolt was misfiring consistently or if all the bolts were misfiring in a random manner. The test showed all the bolts were misfiring at random.

The timing study was re-evaluated; it was found that under extreme conditions 0.030-inch of coast was possible in the firing pin. The fall off point was advanced three degrees and 0.030 inch was added to the fall off side of the "L" slot to correct this situation. During the surface welding of the "L" slot to accommodate the three-degree change, a small crack was initiated in each of the six bolts being welded (see Figure 16). The cracks have in no way affected the operation of these bolts. The aft helix was also moved three degrees to further reduce extract torque. These changes made a significant improvement in bolt operation. No misfires were observed at any rate above 1500 shots per minute (spm).

Further testing indicated a zone between 1000 and 1500 spm where misfires still occurred. It was observed, under certain conditions, the aft pin could work its way out of its required firing position. A small detent (see Figure 17) was added to the aft helix to hold the aft pin in its proper position.

Wear on the forward pin was the only problem remaining. In some cases, this wear amounted to 0.007 inch after 50,000 rounds. The pins were given a greater surface hardness to eliminate this wear. Using the same base material, a new process known as "Tufftriding" gave a surface hardness in the R_c 70's. A set of these specially treated pins presently has been used for over 150,000 rounds with only negligible wear.

Testing after the detent was added and the surface hardness of the forward pin was increased revealed no misfires. In one test, over 10,000 rounds were fired at the previously troublesome rate of 1300 spm without a single misfire.

2. Stoppages

Several stoppages occurred during the testing period. Two did appreciable damage to the assemblies. One bolt head was split along one side in a cook-off situation (see Figure 18). Another bolt was damaged when a defective pit pin allowed the safing sector to open during firing. This resulted in the shearing of a body bolt roller (see Figure 19). The undamaged parts of these two bolts were combined to make one good assembly. This left five of the original six bolts operational. This set of bolts has been tested well over 300,000 rounds. Testing will continue on the set until a complete mechanical failure occurs.

D. MAINTENANCE

Lubrication is of prime importance in bolt assembly maintenance. It has a direct affect on part life and reliability and should always be performed thoroughly and as often as use dictates. Mil-L-46000 is compatible with this assembly. If Mil-L-46000 with teflon is used, the operational life of the assembly will increase. The key lubrication areas are listed below.

1. Aft helix (top and bottom)
2. Head, body interface
3. Firing pin
4. Forward pin*

Both pins must be removed to completely assemble or disassemble these bolts. However, the bolt head, body, and spring can be separated by removing only the aft pin.

The forward pin is held in place by a medium drive press fit. This pin can be assembled from only one direction. When changing this pin make certain the firing pin holes line up with the clearance hole in the bolt head. Do not remove this pin unless it is absolutely necessary. Unnecessary removal will wear both the forward pin and its mating hole, causing the pin to fit loosely and reduce the bolt's efficiency.

The aft pin is held in place by the firing pin spring. Care must be taken in replacing this pin to make sure the flat is correctly aligned. If it is not correctly aligned, the pin may become loose and cause a malfunction.

---

*When the forward pin is lubricated, excessive grease may build up in the "L" slot, causing a malfunction.

A P P E N D I X I-A

Drawings

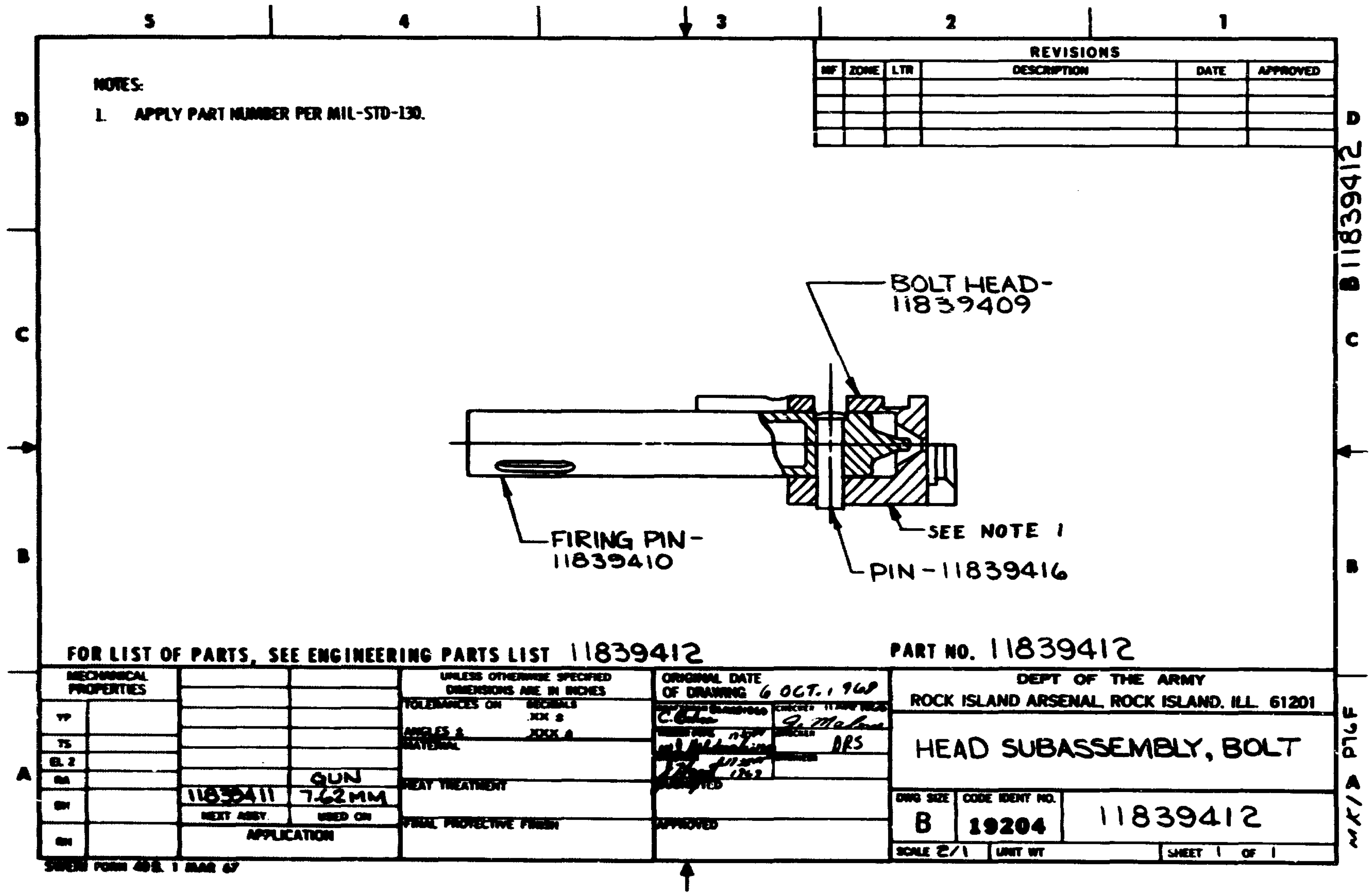


Figure 1. Bolt Head Subassembly

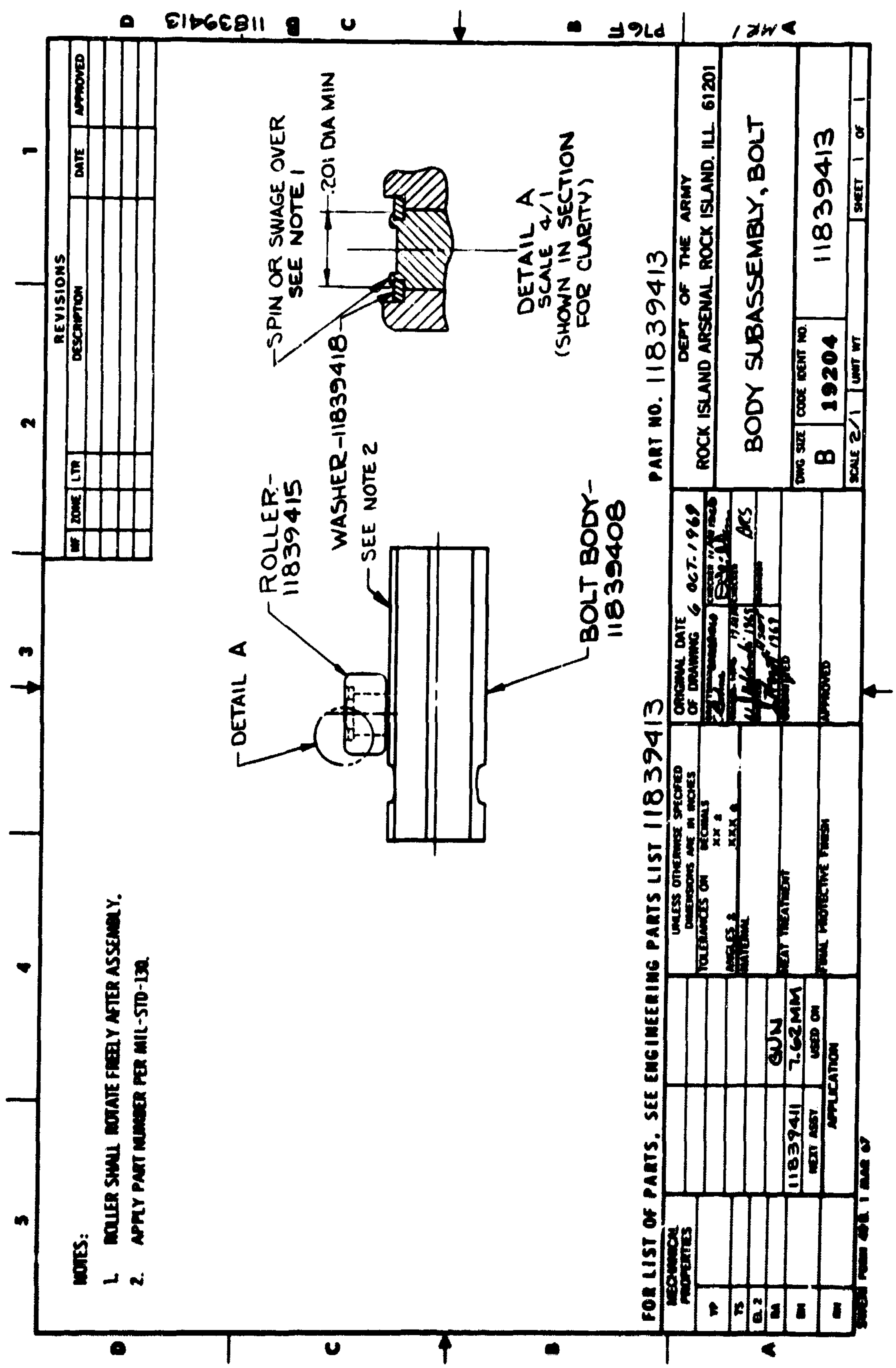


Figure 2. Bolt Body Subassembly

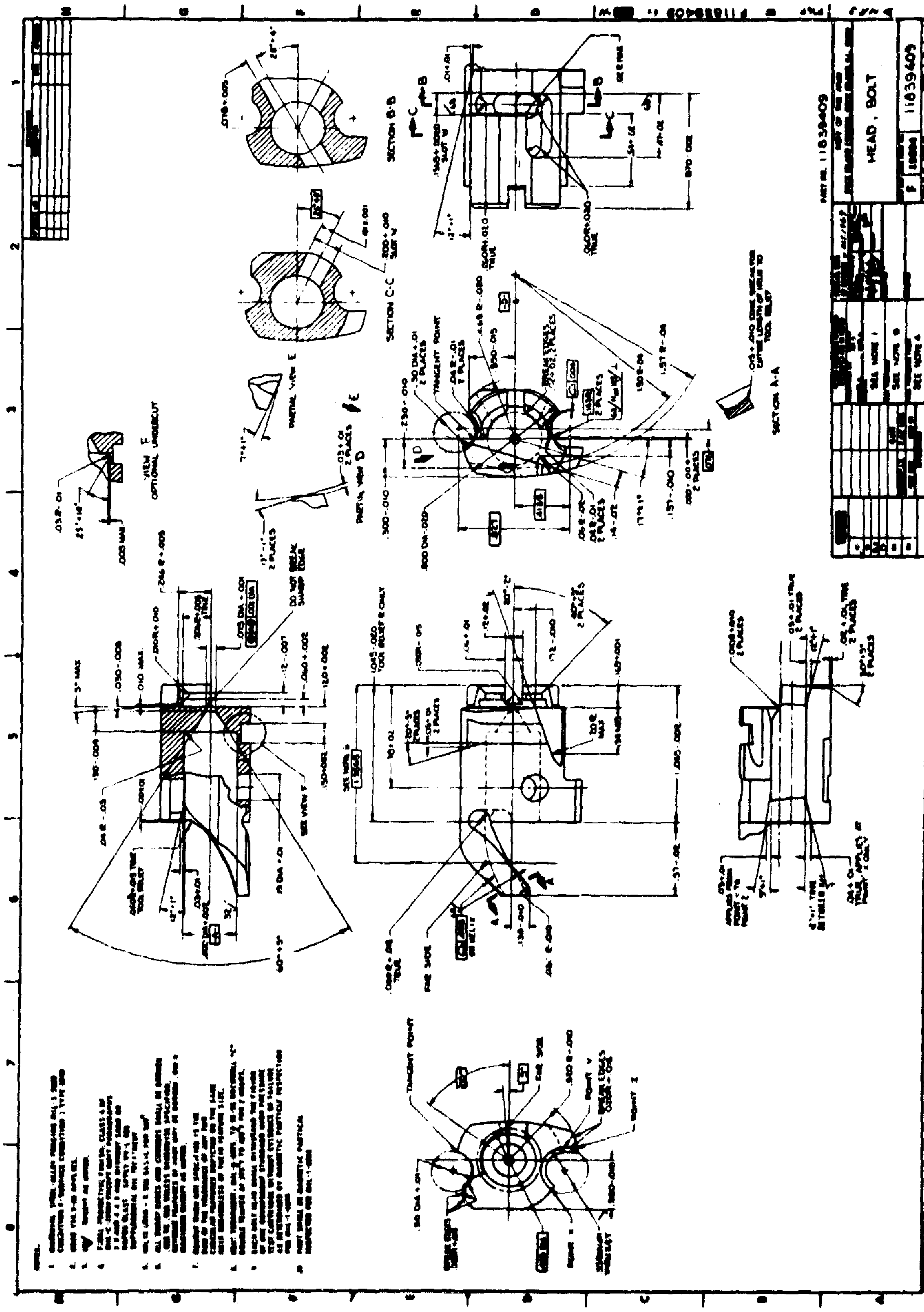


Figure 3. Head Bolt

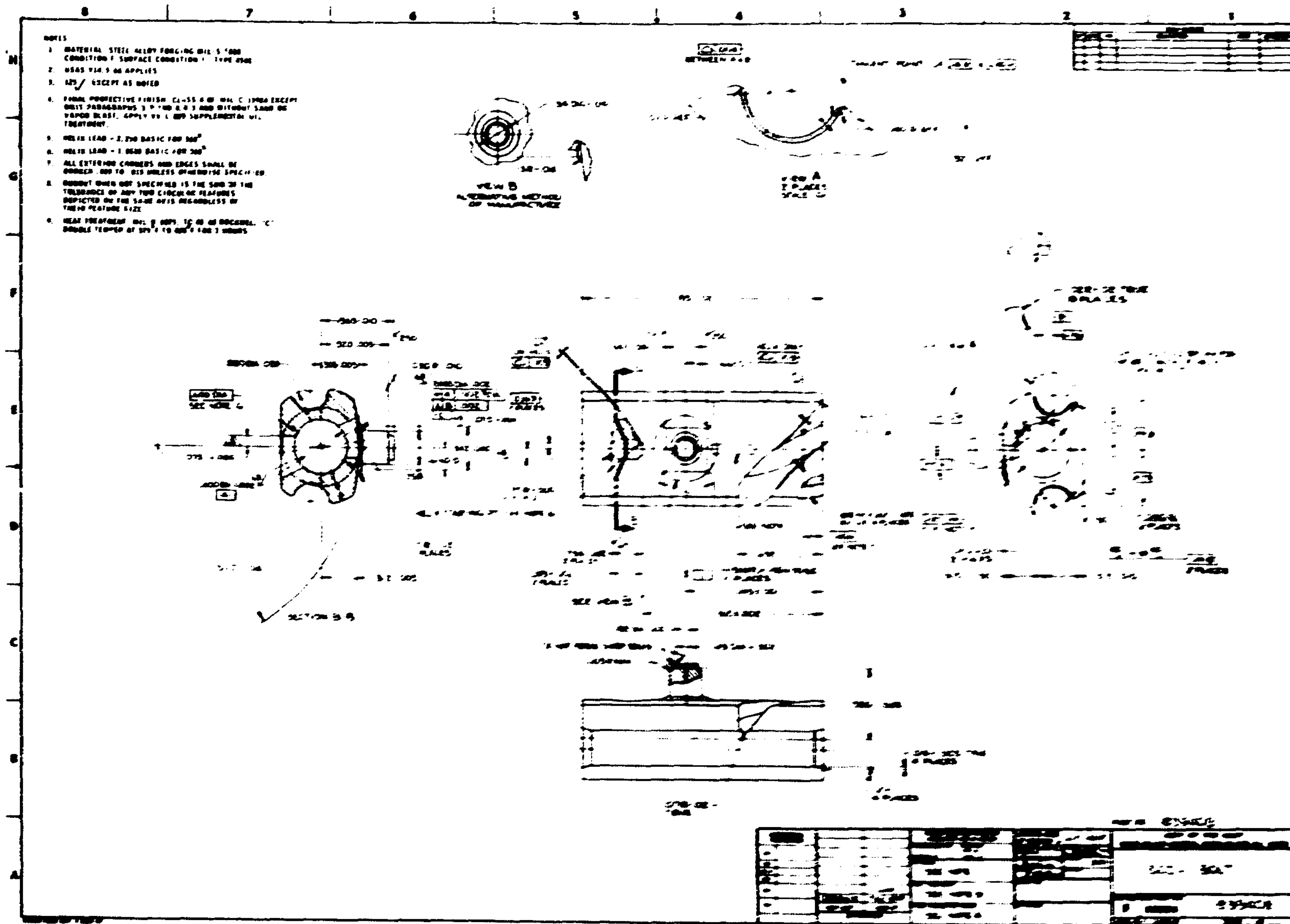


Figure 4. Body Bolt

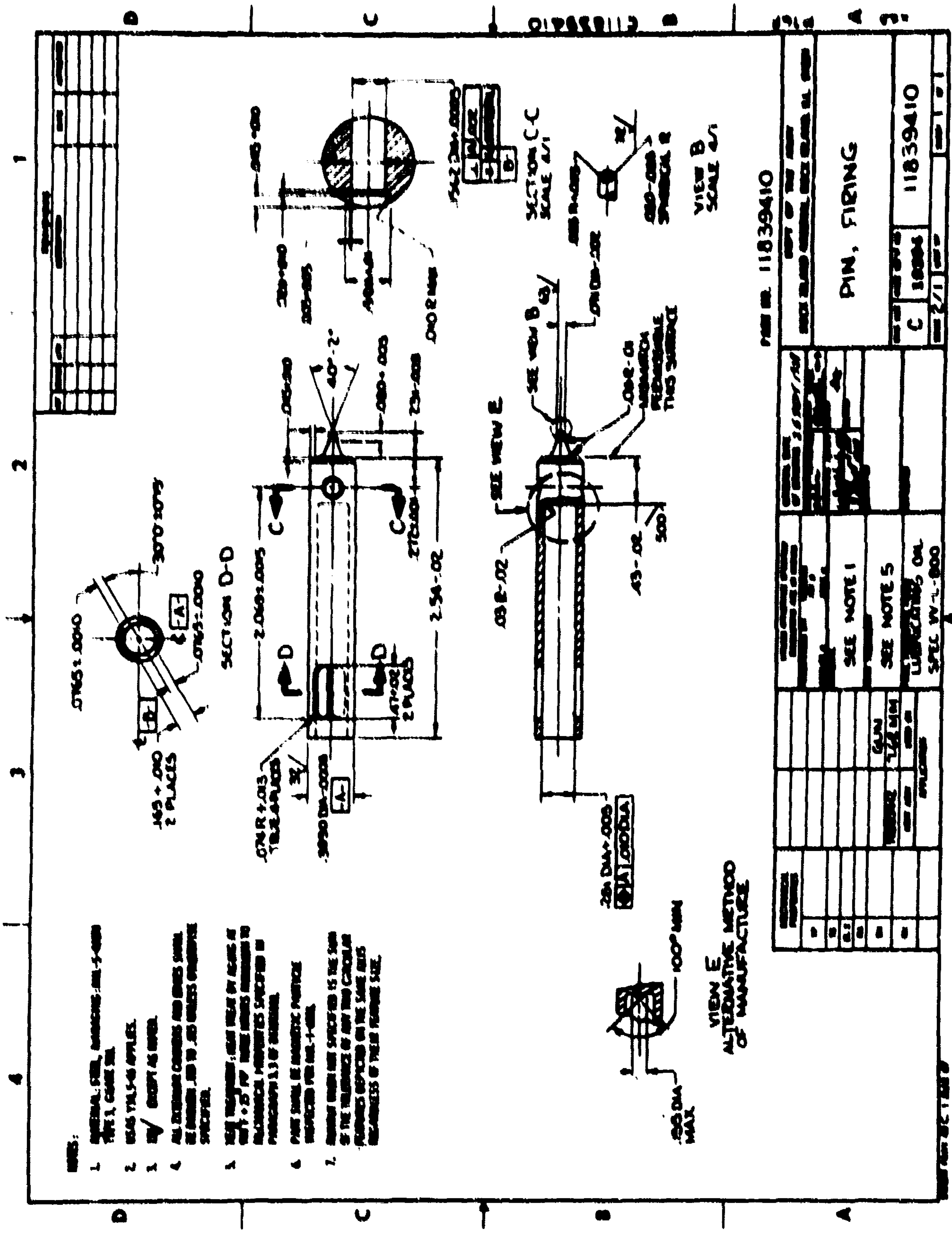


Figure 5. Firing Pin

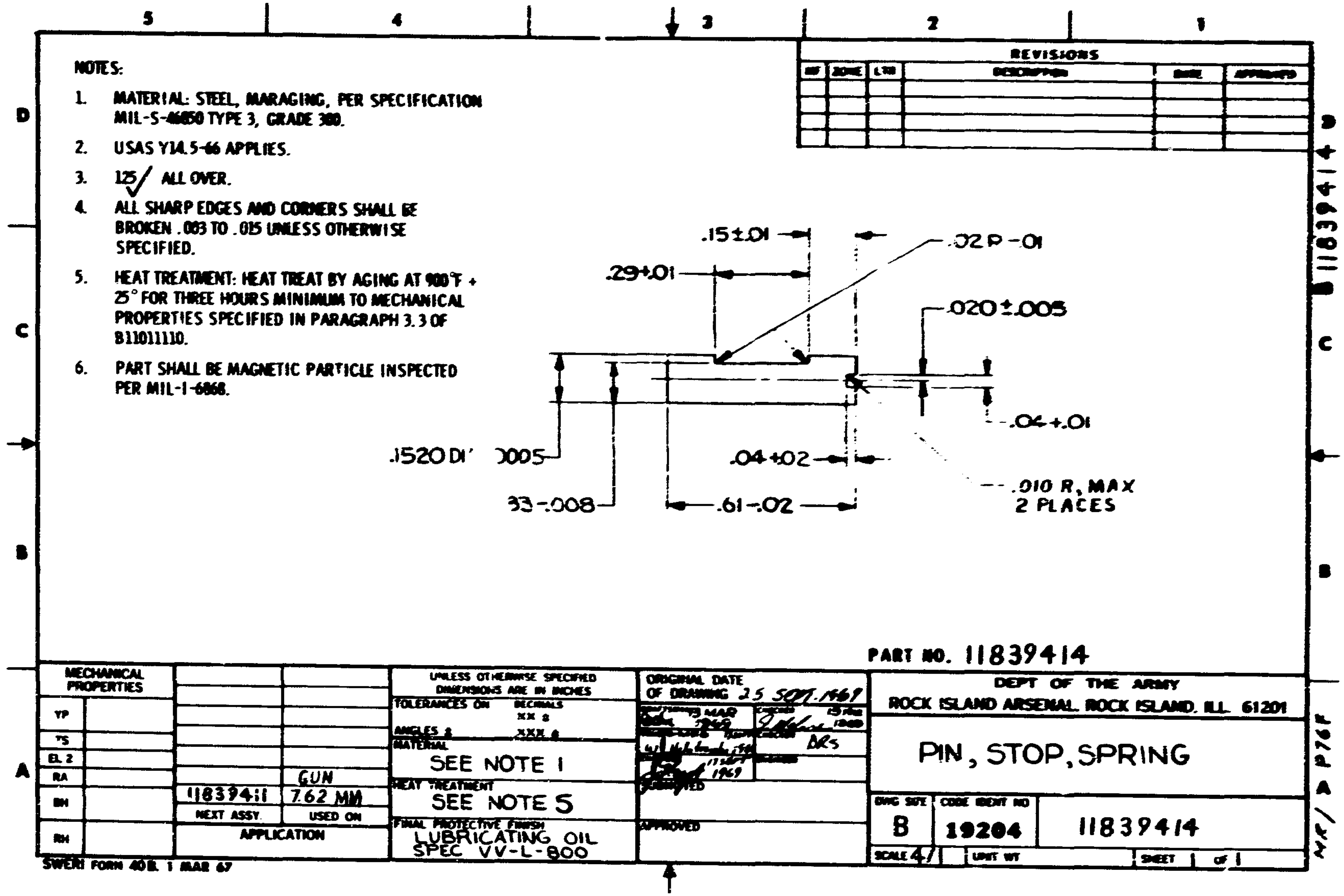


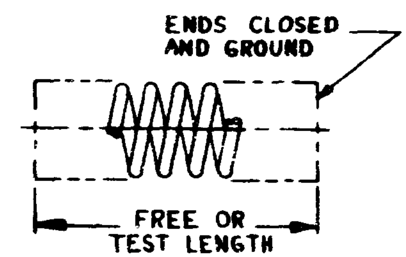
Figure 6. Spring Stop Pin

NOTES:

1. NO PERMANENT SET WILL BE PERMITTED UNDER TEST LOADS.
2. EACH SPRING MUST BE A TRUE HELIX, CONSTANT PITCH AND FREE FROM SCALE AND BURRS.
3. 200,000 POUNDS PER SQUARE INCH ELASTIC LIMIT, MINIMUM.
4. FREE LENGTH DIMENSION SHALL APPLY AFTER SPRING HAS BEEN COMPRESSED TWO TIMES TO SPECIFIED MAXIMUM SOLID HEIGHT.
5. SPECIFICATIONS:

MAXIMUM OUTSIDE DIAMETER	.272
MINIMUM INSIDE DIAMETER	.140
DIRECTION OF HELIX	OPTIONAL
FREE LENGTH	2.18 MIN. 2.22 MAX
MAXIMUM SOLID LENGTH	1.43

6. LOAD AT COMPRESSED LENGTH OF 1.62 = 48 POUNDS MINIMUM, 54 POUNDS MAXIMUM. LOAD AT COMPRESSED LENGTH OF 1.78 = 35 POUNDS MINIMUM, 39 POUNDS MAXIMUM.
7. OPERATING CONDITION:
   100,000 OPERATIONS RESULT IN AN INITIAL LENGHT OF 1.78 TO A FINAL LENGTH OF 1.62. 100,000 IS THE MINIMUM NUMBER OF OPERATIONS REQUIRED WITHOUT INJURY OR PERMANENT SET.



8. TEST LOAD COMPUTED FROM THE FOLLOWING DATA WHICH ARE NOT COMPULSORY FOR MANUFACTURE, EXCEPT WHEN NO TESTS ARE SPECIFIED.

DIA OF WIRE	.060
OUTSIDE DIAMETER	.270
ACTIVE TURNS	22
FREE LENGTH	2.20 (MEAN)
GRADIENT	91.5 LB/INCH DEFLECTION

PART NO. 11839417

REVISIONS					
INF	ZONE	LTR	DESCRIPTION	DATE	APPROVED

MECHANICAL PROPERTIES	YP, TS, EL 2, RA, BH, RH
APPLICATION	NEXT ASSY. 11839411 — USED ON 7.62 MM GUN
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	TOLERANCES ON DECIMALS .XX ± .XXX ±; ANGLES ±
MATERIAL	STEEL CRE 17-7PH(AISI-301PH)
HEAT TREATMENT	
FINAL PROTECTIVE FINISH	OIL VV-L-800
ORIGINAL DATE OF DRAWING	25 SEPT. 1969
DRAFTSMAN	C. Sanford
CHECKED	DRS
APPROVED	
DEPT OF THE ARMY	ROCK ISLAND ARSENAL, ROCK ISLAND, ILL. 612[illegible]
TITLE	SPRING, HELICAL, COMPRESSION
DWG SIZE	B
CODE IDENT NO.	19204
DRAWING NO.	11839417
SCALE	NONE
UNIT WT	
SHEET	1 OF 1

SWERI FORM 40B 1 MAR 67

11839417 P16F

Figure 7. Helical Compression Spring

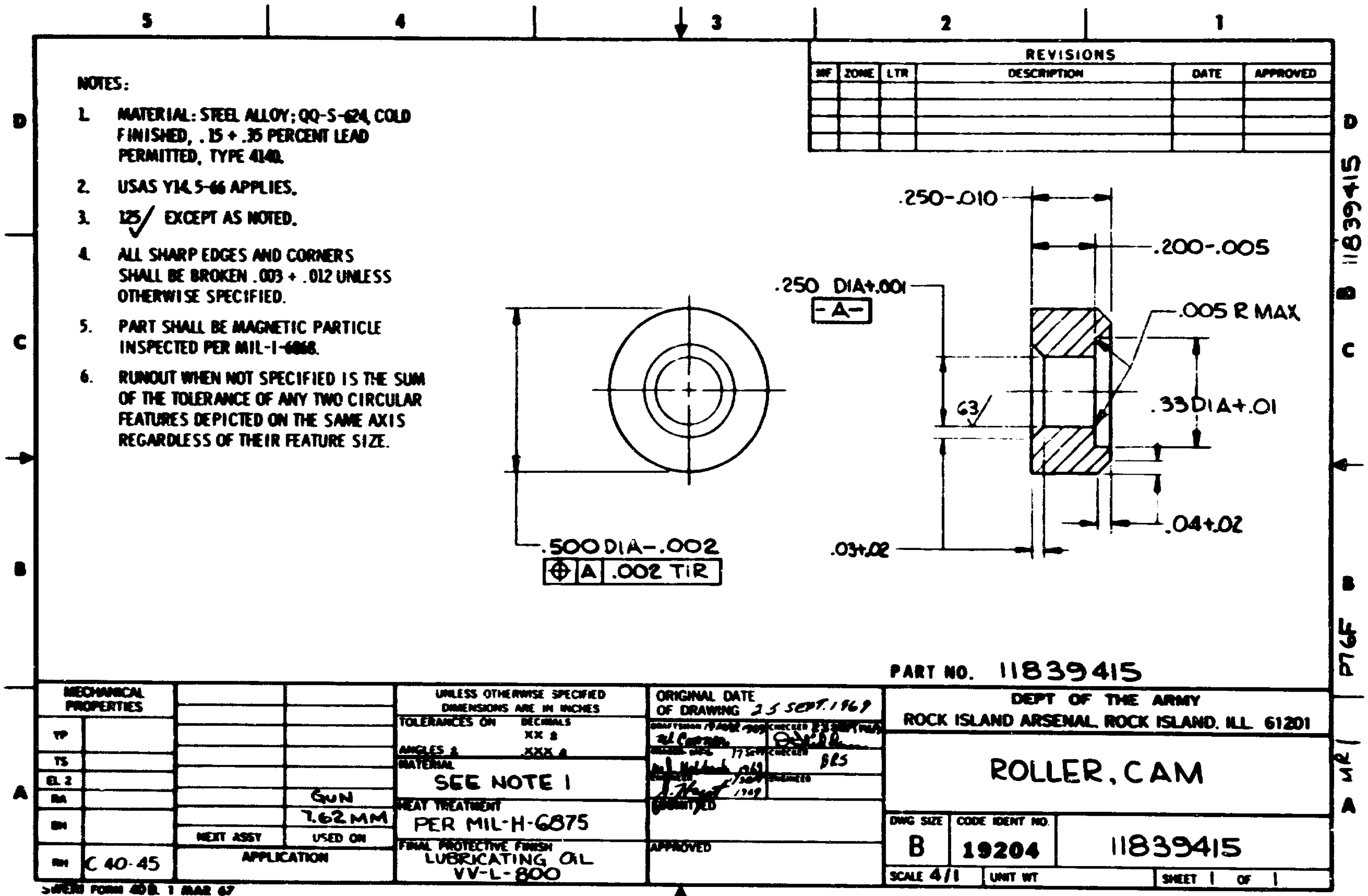


Figure 8. Cam Roller

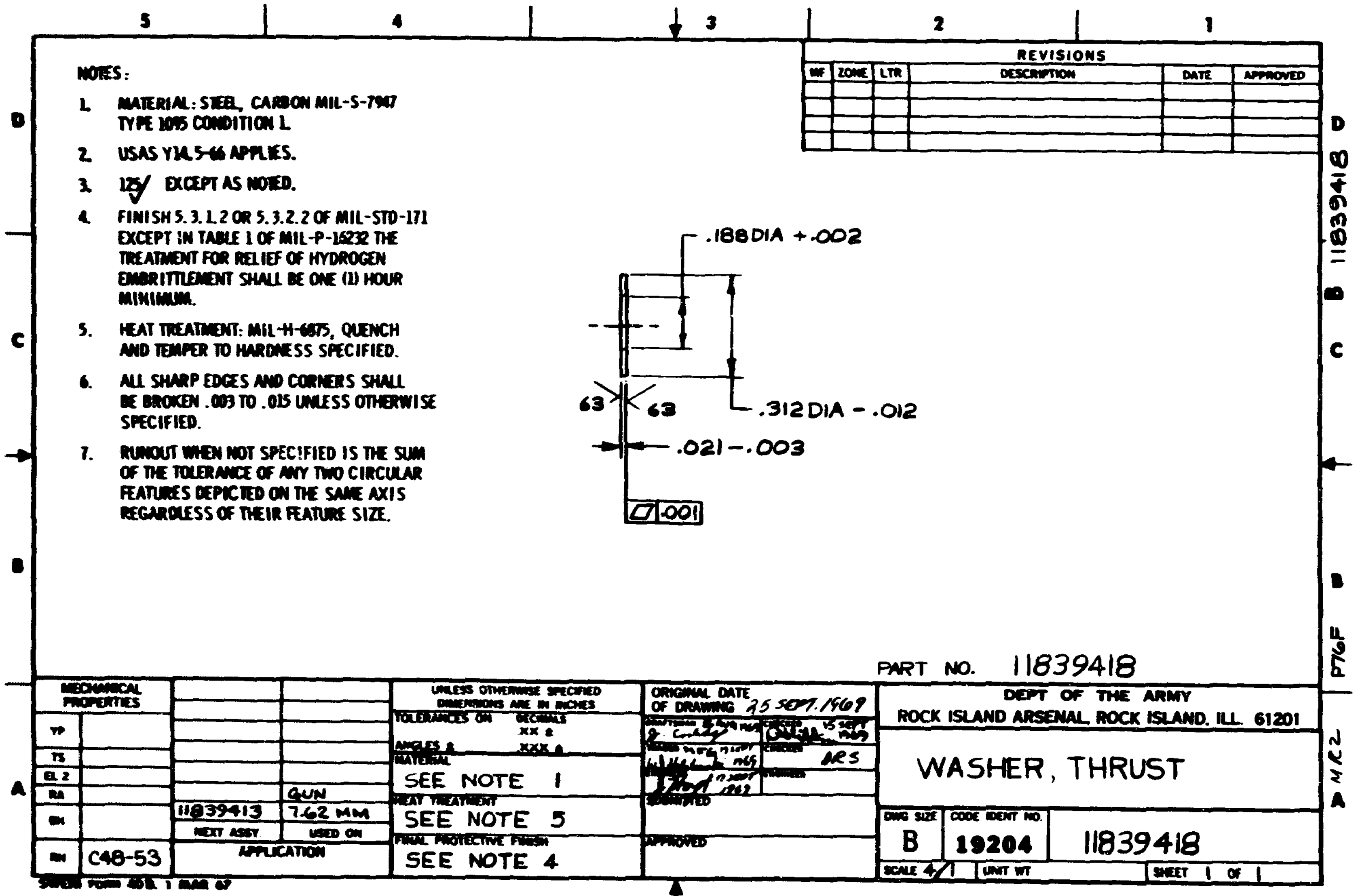


Figure 9. Thrust Washer

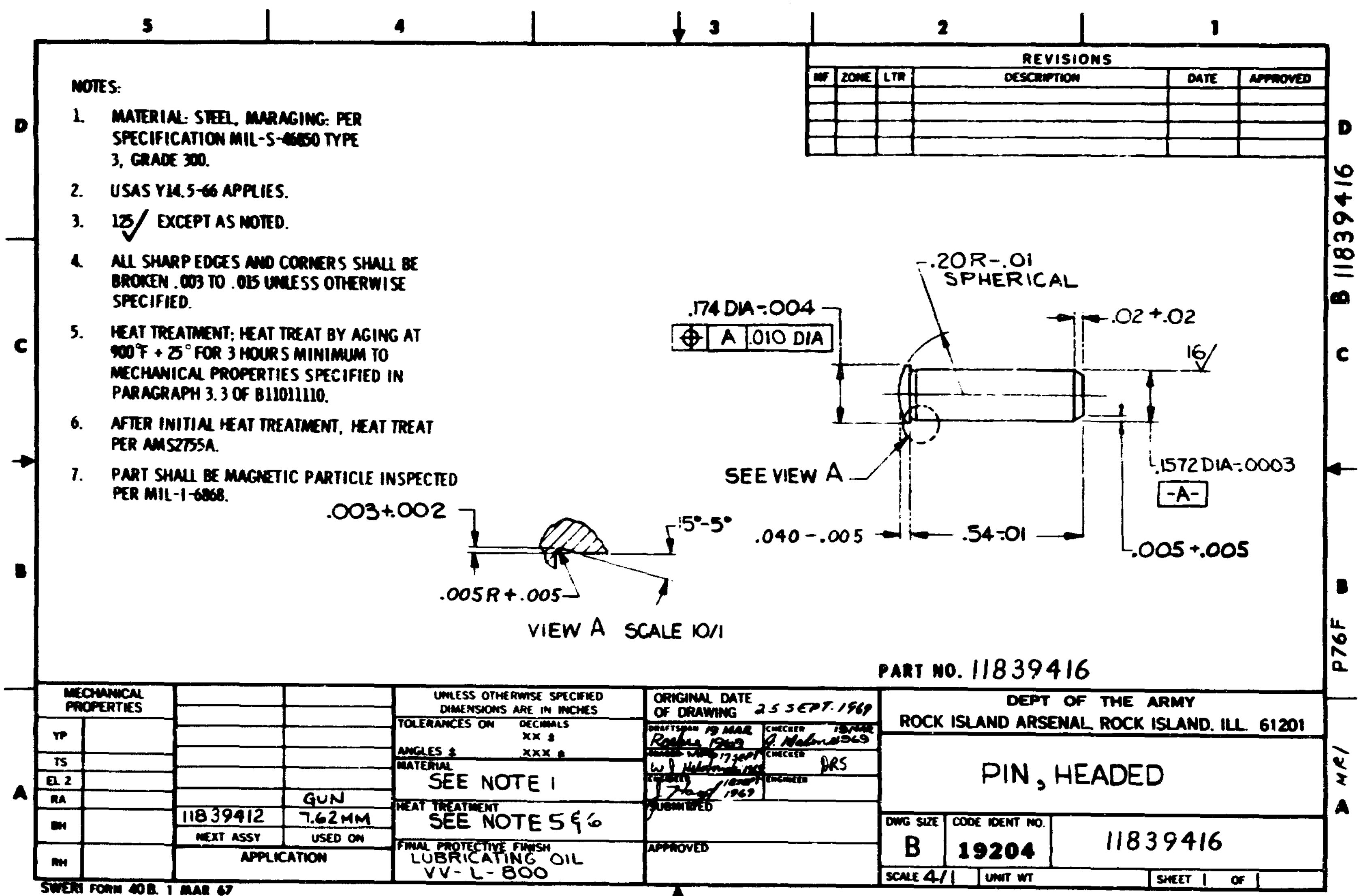


Figure 10. Headed Pin

A P P E N D I X I-B

Photos and Illustrations

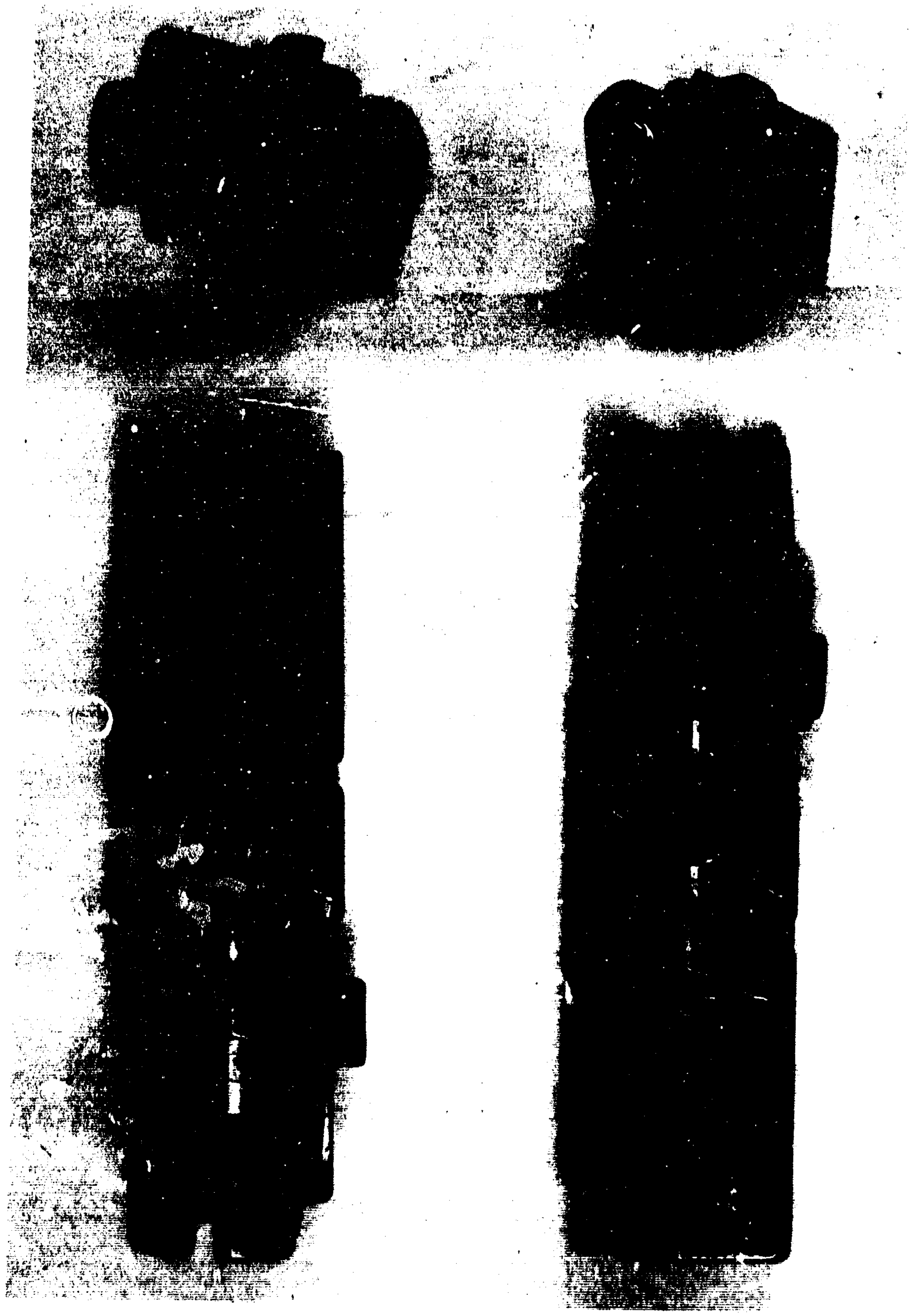


Figure 11. Bolt Assembly

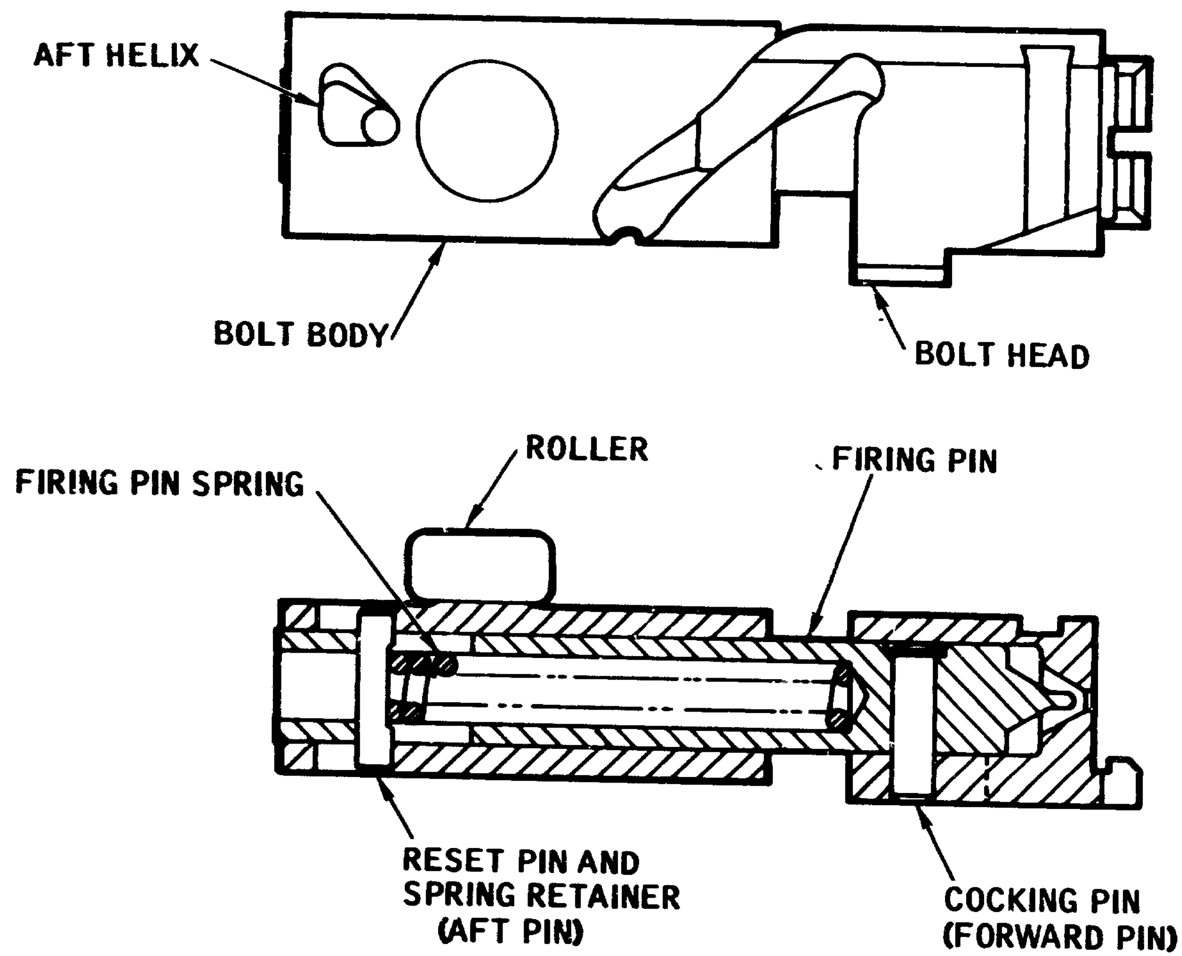


Figure 12. Bolt Assembly

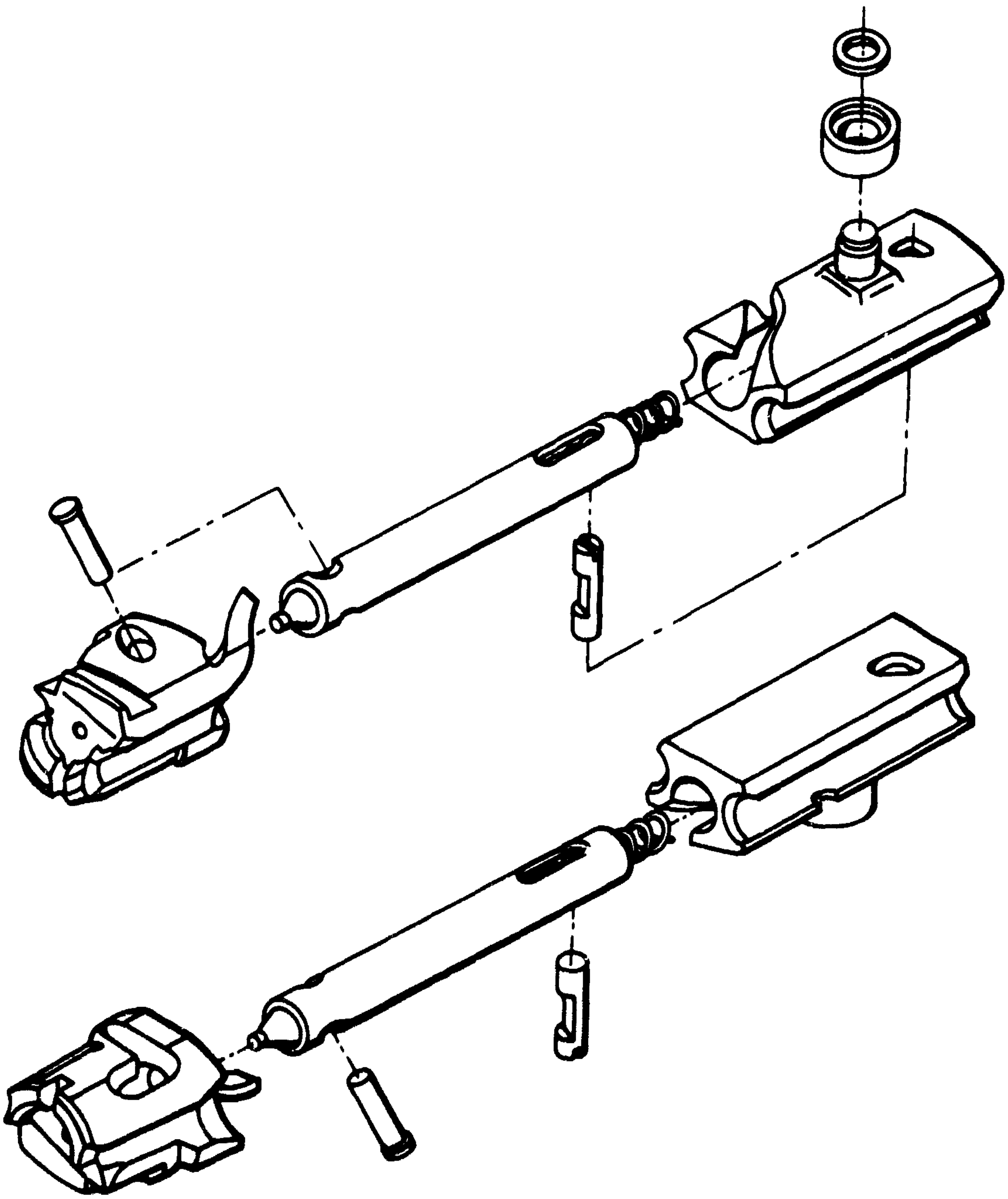


Figure 13. Exploded Bolt Assembly

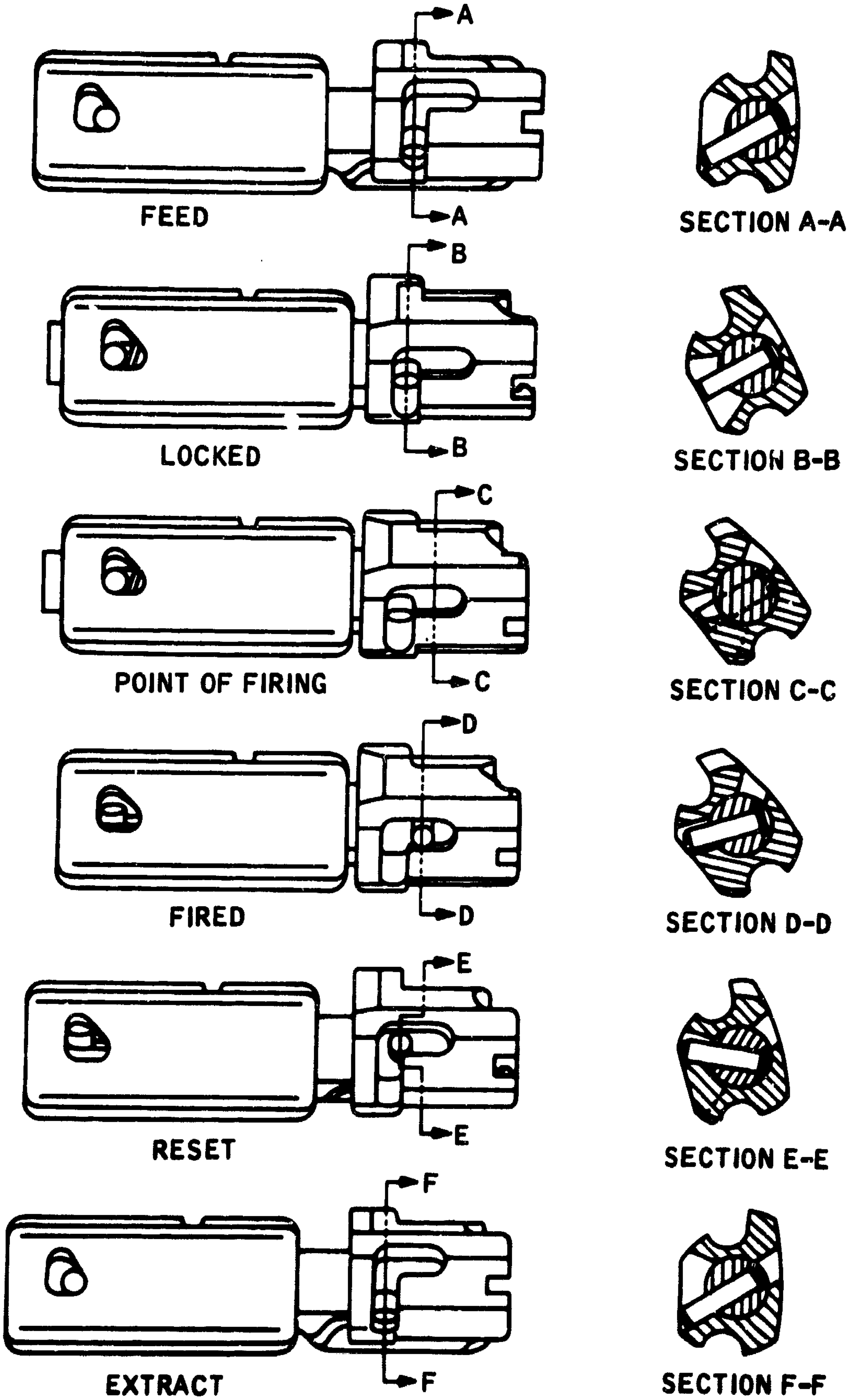
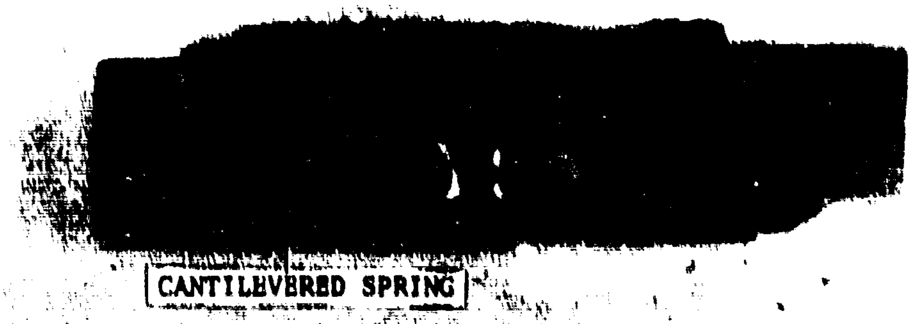
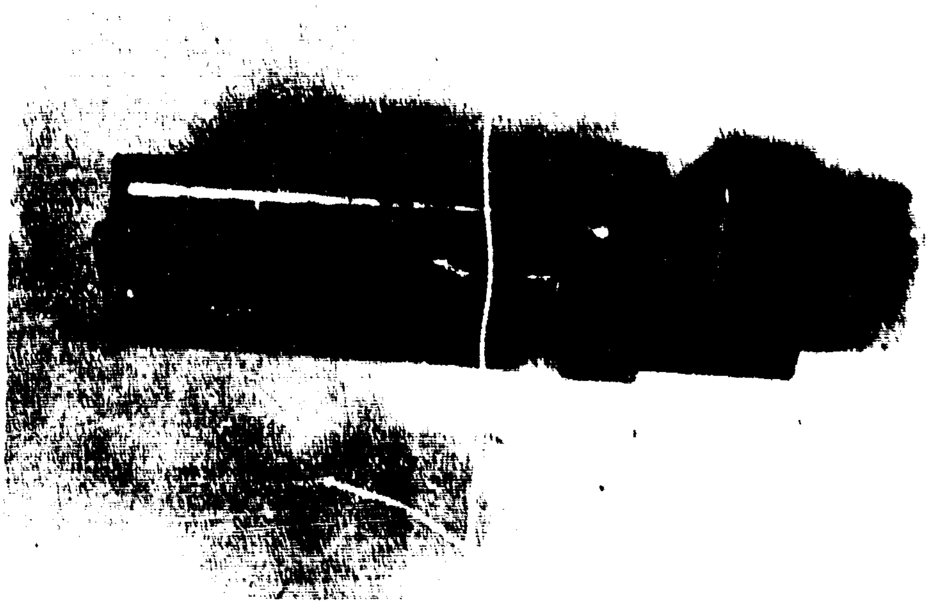


Figure 14. Timing Diagram



(a) (Bottom View)



(b) (Side View)

Figure 15. Modified Bolt Assembly

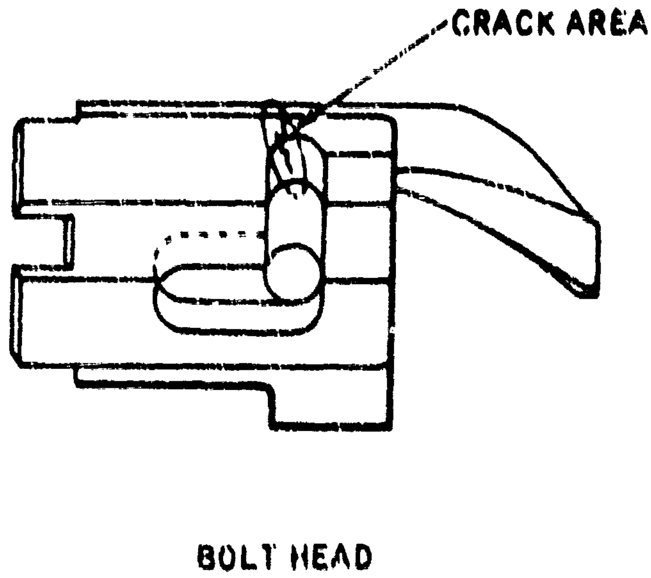


Figure 16. Cracked Bolt Head

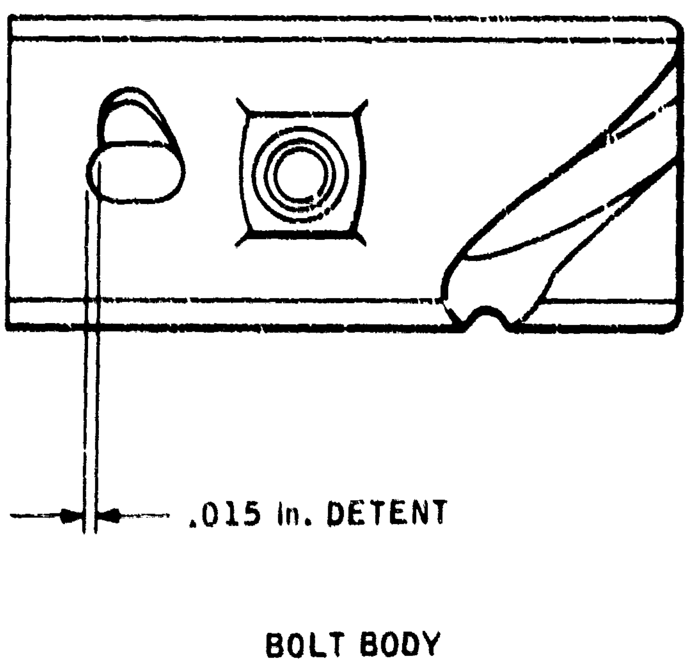
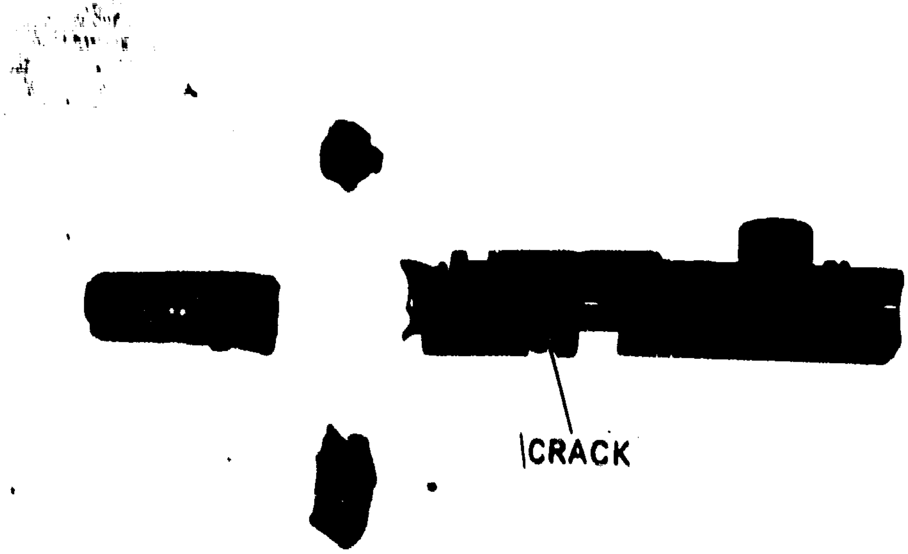
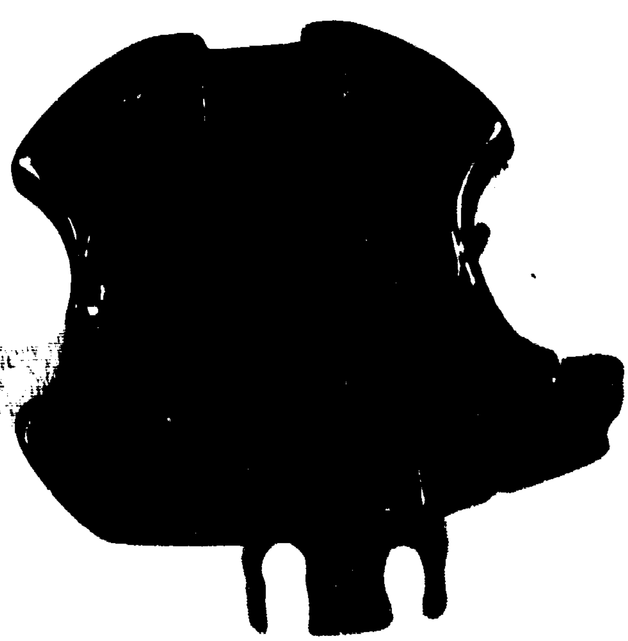


Figure 17. Detent



(a) Bolt Assembly



(b) Bolt Assembly (End View)
Figure 18. Cook-off

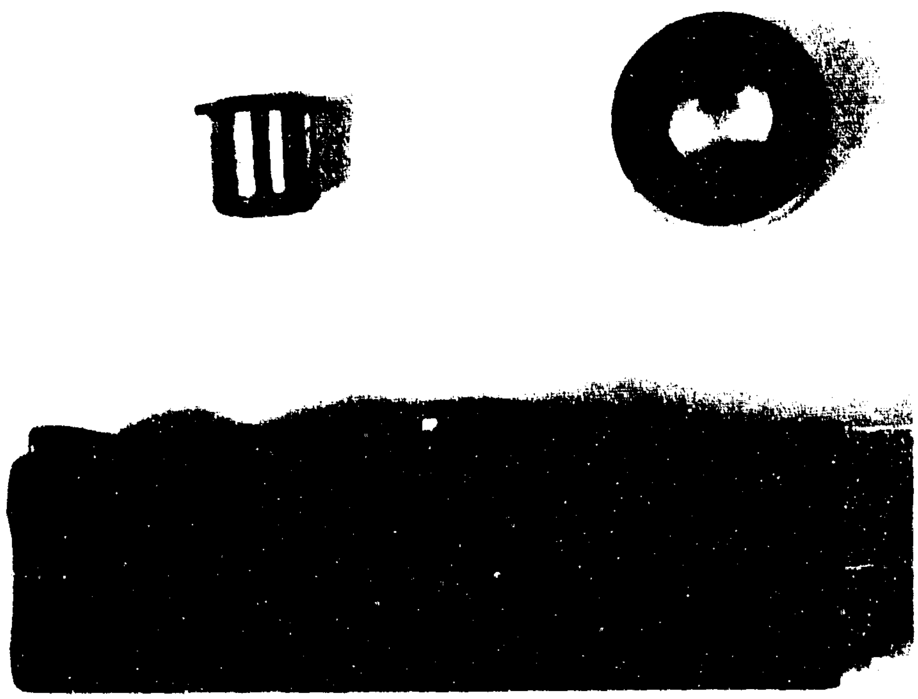


Figure 19. Sheared Roller Stub

```
001 PRINT "THIS IS A SPRING PROGRAM THAT WILL AID IN"
002 PRINT "DEVELOPING NEW SPRINGS.  BEFORE USING THIS"
003 PRINT "PROGRAM CHECK ALL VARIABLES ."
004 PRINT "WHAT IS THE WIRE DIA."
005 INPUT D1
006 PRINT "WHAT IS THE O.D."
007 INPUT D2
008 PRINT "WHAT IS THE FREE HEIGHT"
009 INPUT F3
010 PRINT 2WHAT IS THE COMPRESED HEIGHT"
011 INPUT F2
012 PRINT "WHAT IS THE MAX. WORKIND HEIGHT"
013 INPUT F1
014 PRINT "WHAT IS THE NUMBER OF TURNS"
015 INPUT N
030 LET G=11.5E06
040 LET F=F3-F2
060 LET P=(F*G*D1^4)/(N*8*(D2-D1)^3)
065 LET P1=P
070 LET R=P/(F3-F2)
080 LET C=(D2-D1)/D1
090 LET H=(D2*(N+2))/(C+1)
100 LET S1=(8*P*(D2-D1))/(3.1416*D1^3)
110 LET K=((4*C-1)/(4*C-4))+(.615/C)
120 LET S2=S1*K
130 LET P2=R*(F3-F1)
140 LET E1=((F1-F2)*P2)+(.5*(P1-P2)*(F1-F2))
141 PRINT
142 PRINT "THE MAX. FORCE IS";P
144 PRINT "THE SOLID HEIGHT IS ";H
146 PRINT "THE SPRING RATE IS ";R
148 PRINT "THE SPRING STRESS IS ";S2
150 PRINT "THE SPRING ENERGY IS ";E1
155 PRINT
160 PRINT "DO YOU WANT PIN ENERGY(YES=0,NO=1)";
170 INPUT Z
180 IF Z=1 THEN 310
190 PRINT "WHAT IS THE WEIGHT OF YOUR PIN IN POUNDS"
```

Figure 20. (Sheet 1 of 2) Computer Program for Self-Actuating Bolts

```
200 INPUT W
210 LET M1=W/386
220 LET S=S2
240 LET I=(3.1416*S*D1^3)/(16*((D2-D1)/2)*K)
250 LET J=(G*D1^4)/(64*N*((D2-D1)/2)^3)
260 LET M2=((D2-D1)*3.1416*(N+2)*3.1416*(D1/2)^2*.282)/386
270 LET M3=M1+(M2/3)
280 LET V2=(((2*I)/M3*(F1-F2))-((J/M3)*(F1-F2)^2)
290 LET E2=.5*M3*V2
300 PRINT "THE VALUE OF E2 IS";E2
305 PRINT
310 PRINT "DO YOU WANT PIN VELOCITIES(YES=0,NO=1";
320 INPUT Q
330 IF Q=1 THEN 410
340 PRINT "THIS PART OF THE PROGRAM GIVES A THEO VALUE OF"
342  PRINT"PIN VELOCITY , ACCELERATION , AND TIME FOR EVERY"
344 PRINT ".01 INCHES OF TRAVEL STARTING FROM REST ."
350 PRINT "DISTANCE            VEL              ACC              TIME"
355 LET K=0
360 LET F4=F2
365 LET F4=F4+.01
370 LET V2=((((2*I)/M3)*(F4-F2))-((J/M3)*(F4-F2)^2)
380  LET V=SQR(V2)
382 LET A=(I-J*(F4-F2))/M3
384 LET T=(1.0/V)*(F4-F2)
390 IF F4>F1 THEN 410
400 PRINT F4,V,A,T
402 IF K=1 THEN 413
405 GO TO 365
410 LET F4=F1
411 LET K=1
412 GO TO 370
413 PRINT "DO YOU WANT TO TRY AGAIN(YES=0, NO=1)";
420 INPUT X
430 IF X=1 THEN 450
440 GO TO 04
450 END
```

Figure 20. (Sheet 2 of 2) Computer Program for Self-Actuating Bolts

```
THIS IS A SPRING PROGRAM THAT WILL AID IN
DEVELOPING NEW SPRINGS.  BEFORE USING THIS
PROGRAM CHECK ALL VARIABLES .
WHAT IS THE WIRE DIA.
? .060
WHAT IS THE O.D.
? .270
WHAT IS THE FREE HEIGHT
? 2.20
WHAT IS THE COMPRESED HEIGHT
? 1.62
WHAT IS THE MAX. WORKIND HEIGHT
? 1.78
WHAT IS THE NUMBER OF TURNS
? 22.0

THE MAX. FORCE IS 53.0347
THE SOLID HEIGHT IS  1.44
THE SPRING RATE IS 91.4392
THE SPRING STRESS IS  193761.
THE SPRING ENERGY IS  7.31513

DO YOU WANT PIN ENERGY(YES=0,NO=1)? 0
WHAT IS THE WEIGHT OF YOUR PIN IN POUNDS
? .0514
THE VALUE OF E2 IS 7.31513

DO YOU WANT PIN VELOCITIES(YES=0,NO=1)? 0
THIS PART OF THE PROGRAM GIVES A THEO VALUE OF
PIN VELOCITY , ACCELERATION , AND TIME FOR EVERY
.01 INCHES OF TRAVEL STARTING FROM REST .
```

DISTANCE	VEL	ACC	TIME
1.63	85.4356	361789.	1.17047E-04
1.64	120.298	355442.	1.66254E-04
1.65	146.686	349094.	2.04518E-04
1.66	168.628	342747.	2.37209E-04
1.67	187.688	336400.	2.66399E-04
1.68	204.674	330053.	2.93149E-04
1.69	220.066	323706.	3.18087E-04
1.7	234.178	317359.	3.41620E-04
1.71	247.231	311011.	3.64032E-04
1.72	259.384	304664.	3.85529E-04
1.73	270.758	298317	4.06267E-04
1.74	281.448	291970.	4.26367E-04
1.75	291.528	285623.	4.45926E-04
1.76	301.061	279276.	4.65022E-04
1.77	310.096	272928	4.83721E-04
1.78	318.677	266581	5.02076E-04
1.78	318.677	266581.	5.02076E-04

```
DO YOU WANT TO TRY AGAIN(YES=0,NO=1)? 1
```

Figure 21. Computer Output for Self-Actuating Bolts

A P P E N D I X I-C

Test Results

Table I. R & D Tangless Bolts Firing Schedule

Bolt Arrangement

Bolt Set	Bolt Body No.	Bolt Set	Bolt Body No.
1	2, 3, 4, 8, 9, 12	1b	3, 7, 8, 9, 12, Prod. bolt
2	5, 6, 7, 10, 13, 14	1c	3, 7, 8, 9, Prod. bolt, Prod. bolt
1a	2, 3, 7, 8, 9, 12	1d	2+, 3, 7, 8, 9, Prod. Bolt
2a	5, 6, 4, 10, 13, 14	A	7, 8, 9, 10, 13, 14
		B	10, 13, 14, 4*, 5*, 6*

Bolt Set	Firing Date	Rounds Fired	System	Remarks
1	3/24/69	22,000	R&D feeder prod. pod	
2	3/24	49,600	XM 21 stand w/clutch	
2	5/6	1500	A-37 blast tube	
1	5/9	9000	R&D feeder prod pod	
2	5/12	1500		
1	5/12	4500		
2	5/12	7500		
1	5/12	7500		
1	5/13	13,500		
1a	6/3	5200	XM 21 stand	Bolt assemblies 4 and 7 exchanged between sets
2a	6/3	100		
1a	6/4	6000		
1a	6/9	4400	A-37 w/clutch	
A	6/17	20,000	XM 21 stand	Amount of lubrication varied
B	6/18	8000	XM 21	Cantilever spring on 3 assys.
1a	6/18	8000	XM 21 stand	Safing sector moved to different spacings
1a	6/19	12,000		Rates varied
B	6/19	8000		

Table I. R & D Tangless Bolts Firing Schedule (cont.)

Bolt Set	Firing Date	Rounds Fired	System	Remarks
1a	7/9	12,000		
1a	7/10	8000		
1a	7/31	11,000	XM 21 stand w/clutch	
1a	8/1	10,500		
1a	8/4	9000		
1a	8/5	6000		
1a	8/7	11,700		
1a	8/8	11,000	XM 21 clutch	Cook-off split bolt head bolt assy. (body 2) replaced by prod. bolt assy.
1b	8/13	4500	XM 21	New bolt set (std. instead of bolt assy. 2)
1b	8/14	9000		
1b	8/29	10,000		Detent added to aft helix in rear of bolt body
1b	9/3	12,000	R&D pod w/R&D feeder	
1b	9/8	9000		Stoppage - safing sector pin came loose - bolt assy. (body 12) sheared bolt roller
1c	9/8	36,000		
1c	9/9	3000		
1d	9/9	45,000		Note: + in Bolt Arrangement
1d	9/10	3000	XM 21 stand	
1d	9/30	1500		
Total		400,500		

+ Bolt body 2 (from cook-off on 8/8/69, which cracked the bolt assembly head) combined with bolt head 15 (from sheared roller stud on 9/8/69, which lost the bolt body 12)

* Special bolt assemblies with a cantilever spring added to the rear pin (reset pin in bolt body).

Table II. Total Rounds on R&D Bolt Assemblies
by Bolt Body Number

Body No.	Rounds Fired	Sets Appearing in
2	36,800	1, 1a, 1a
3	47,217	1, 1a, 1b, 1c, 1d
4	12,000	1, 2a, B
5	12,700	2, 2a, B
6	12,700	2, 2a, B
7	51,067	2, 1a, 1b, A, 1c, 1d
8	50,550	1, 1a, 1b, A, 1c, 1d
9	50,550	1, 1a, 1b, A, 1c, 1d
10	16,022	2, 2a, A, B.
12	40,717	1, 1a, 1b, 1d
13	16,022	2, 2a, A, B
14	16,022	2, 2a, A, B
Body 2 + Head 15	8250	1d

APPENDIX I-D

Weight and Center of Gravity

Weight and Center of Gravity

The production and self-actuating bolts are approximately the same weight, with the self-actuating being slightly heavier. For location of the center of gravity see enclosed sketch.

	Design	Weight (Pounds)
1.	Self-actuating	0.22661
2.	Production	0.21063

Weight increase per bolt = 0.01598 pound

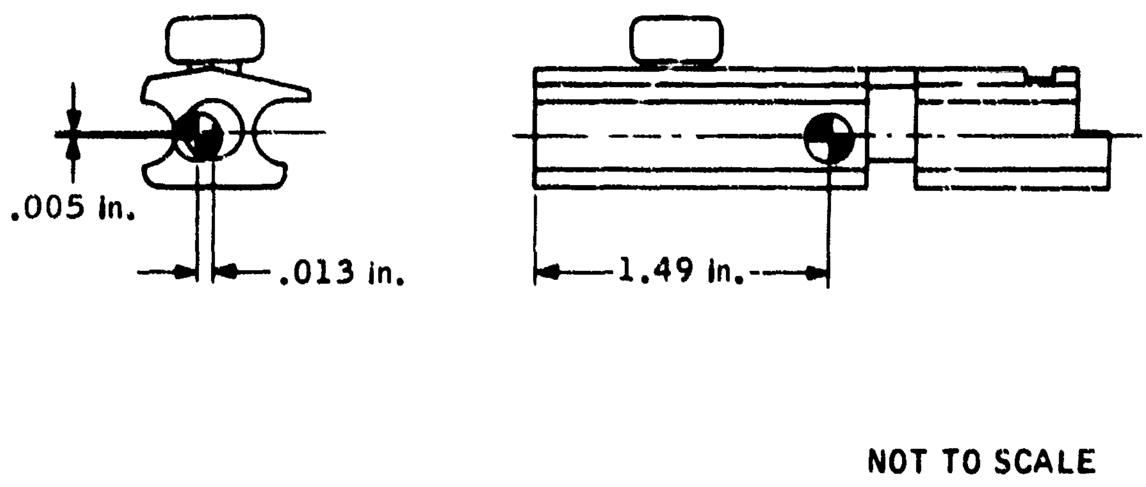


Figure 22. Center of Gravity of Bolt

TECHNICAL ANALYSIS FORM

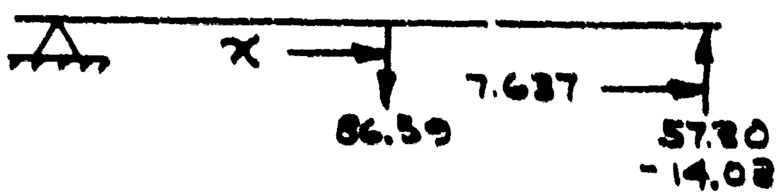
BY RAYMOND CK DATE 10-24-69 REV	GENERAL ELECTRIC	PAGE 1 MODEL REPORT

CENTER OF GRAVITY STUDY FOR SELF-ACTUATING BOLTS

EQUIPMENT: (1) BEAM BALANCE (GRAMS)
(2) KNIFE EDGES
(1) SUPPORT BEAM

WEIGHTS: (1) BOLT = 125.34 GR
(2) BEAM = 86.59 GR
(2) KNIFE EDGES 14.02 GR

C.G. OF BEAM SUPPORT



$$x = \frac{(57.30 - 14.02)(7.637)}{86.59}$$

$x = \underline{3.8162 \text{ IN.}}$

(CONT)

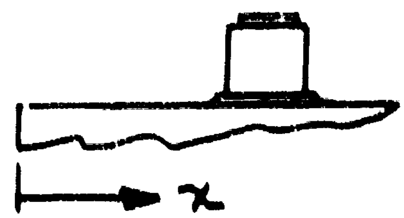
024-888 (8-66)

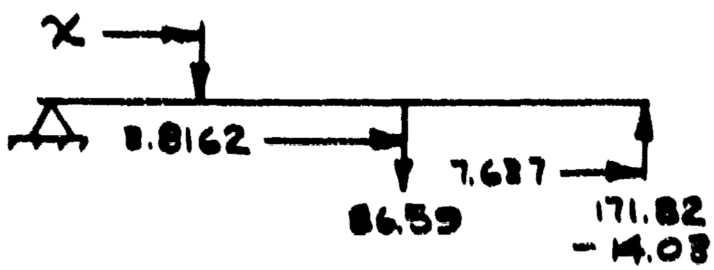
TECHNICAL ANALYSIS FORM

BY RAYMOND CK DATE 10-24-60 REV.	GENERAL ELECTRIC	PAGE 2 MODEL REPORT

CENTER OF GRAVITY STUDY

X DIRECTION:

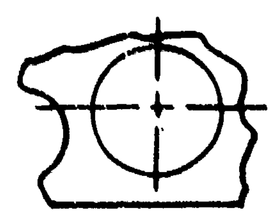




$$x = \frac{(7.637)(171.82-14.03)-(86.59)(3.8162)}{125.35}$$

$$x = 6.9778 - 5.487 = \underline{1.4908\ \text{IN.}}$$

y DIRECTION:



$$y = \frac{(7.637)(153.12-14.03)-(86.59)(3.8162)}{125.35}$$

$$y = 5.8284 - 5.4870 = \underline{.3514\ \text{IN.}}$$

024-880 (8-60

TECHNICAL ANALYSIS FORM

BY RAYMOND CK DATE 10-24-69 REV.	GENERAL ELECTRIC	PAGE 3 MODEL REPORT

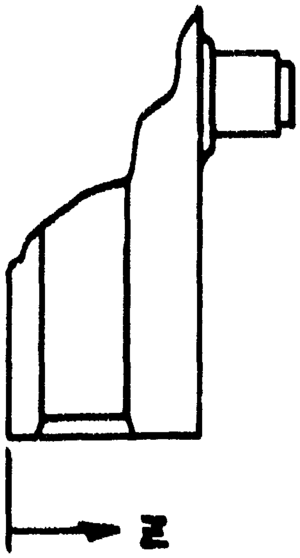
CENTER OF GRAVITY STUDY

Z DIRECTION:

$$Z = \frac{(7.637)(151.72-14.02)-(64.50)(3.8162)}{123.35}$$

$Z = 5.7537 - 5.4870$

$Z = \underline{.3050 \text{ IN.}}$



084-580 (8-59)

APPENDIX I-E

Tolerance Study

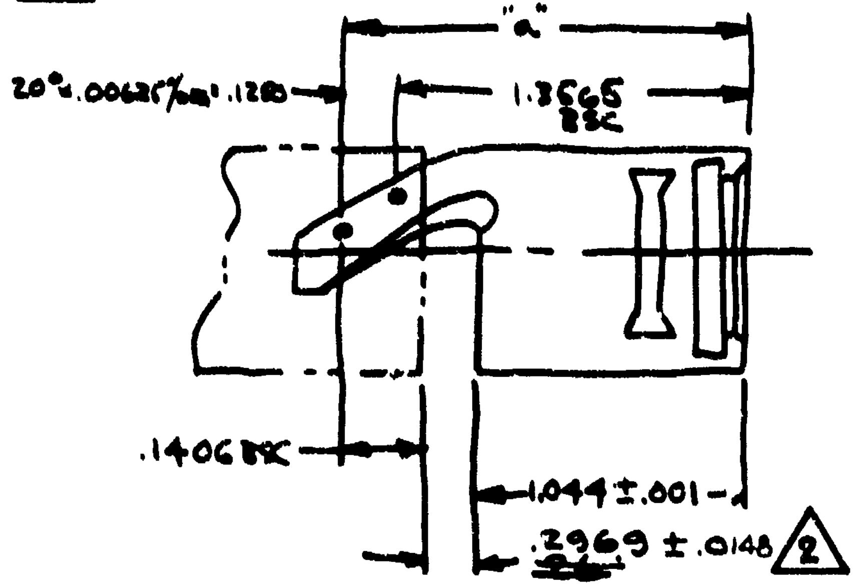
TECHNICAL ANALYSIS FORM

BY D. GLIDDEN CK. DATE 9 OCT 1969 REV.	GENERAL ELECTRIC	PAGE 1 OF 9 MODEL 7.62MM REPORT

TANGLESS BOLT TOLERANCE STUDY (DWG 11839411)

I. TO FIND CLEARANCE BETWEEN BODY HELIX & AFT PIN (WITH ROUND SEATED):

.869 ±.001 FRONT OF BOLT TO SLOT
-.1575±.0005 WIDTH OF COCKING SLOT
=.7115±.0015="c"
1.044 ±.001 LG. OF BOLT HD.
△1 .3325±.0025



1.3565 BSC
+ .1250 "
1.4815 BSC "a"
- 1.0440 ±.0010
.4375 ±.0010
- .1406 BSC
.2969 ±.0010
~~ ±.0107 AXIAL TOL OF HELIX
~~ ±.0031 = 1° CLR ON HELIX (.00625/DEG)
.2969 ±.0148 △2

COT. HELIX ANGLE = $\frac{2.250}{\pi \cdot .485}$
= 1.47669
= 34°7'

34°7'
x = COSEC 34°7' (.006)
= .0107
.006 TOL ZONE

TECHNICAL ANALYSIS FORM

BY D. GLIDDEN CK. DATE 9 OCT 1969 REV.	GENERAL ELECTRIC	PAGE 2 OF 9 MODEL 7.62 REPORT

TANGLESS BOLT TOLERANCE STUDY (DWG 11839411)

I. (CONT)

```
    .3325 ± .0025  △1
    .2969 ± .0148  △2
   1.365  ± .002   LOC. OF HELIX
   1.9944 ± .0193 = "b"

    .0786          1/2 FWD PIN DIA
 + 2.0690 ± .0015  LOC AFT PIN
   2.1476 ± .0015
△3 - .1518 ± .0002  AFT PIN DIA
   1.9958 ± .0017
△4 - 1.9944 ± .0193  "b"
    .0014 ± .0210   CLR
```

II. TO FIND TRAVEL OF FIRING PIN:

```
    .7115 ± .0015  "c" (SEE CALC. I)
  - .1695 ± .0005  EXTRACT LIP
    .5420 ± .0020 = LOC OF COCKING SURF
  - .1860 ± .0040  BOLT HD THK
    .3560 ± .0060
  - .1934 ± .0025  "d"
△5  .1626 ± .0085  PIN TRAVEL

    .272  ± .001   LOC OF PIN IN F.P.
  - .0786 ± .0015  1/2 FWD PIN DIA
    .1934 ± .0025 = "d" SEE ABOVE
```

TECHNICAL ANALYSIS FORM

BY D.GLIDDEN CK. DATE 9 OCT 1969 REV.	GENERAL ELECTRIC	PAGE 3 OF 9 MODEL 7.62MM REPORT

TANGLESS BOLT TOLERANCE STUDY

III. AFT PIN CLEARANCE:

.0014 ±.0210 △4
+ .1518 ±.0002 AFT PIN DIA
— .1532 ±.0212
.248 ±.001 LG OF AFT HELIX
△6 .0948 ±.0222 CLR

IV. TO FIND CAM ROLLER TRAVEL:

1.6875 ±.0005 [-B-] TO BACK OF BARREL
1.0440 ±.0010 BOLT HD LG
.2969 ±.0148 △2
1.0450 ±.0010 TO ℄ OF ROLLER
~ ±.0017 "a"
.2495 ±.0005 1/2 CAM ROLLER
△7 4.3229 ±.0195

.251 x ROLLER ID
−.2475 n STUD
.0035 x CLR
÷2 = ±.0017 = "a"
SEE ABOVE

.0610 ±.0010 LOC OF BRG
.4980 ±.0008 BRG THK
4.0940 ±.0010 [-E-] TO SAFE SECT.
4.6530 ±.0028
− .625 ±.001 CAM DWELL
△8 4.0280 ±.0038 [-B-] TO CAM DWELL

4.3229 ±.0195 △7
−4.0280 ±.0038 △8
△9 .2949 ±.0233 CAM ROLLER TRAVEL

024-889 (9-69)

TECHNICAL ANALYSIS FORM

BY D. GLIDDEN CK. DATE 9 OCT 1969 REV.	GENERAL ● ELECTRIC	PAGE 4 OF 9 MODEL 7.62 MM REPORT

TANGLESS BOLT TOLERANCE STUDY

V. TO FIND INITIAL SPRING HGT:

.1290 ± .0040 FLAT OF AFT PIN
+.420 ± .010 LOC OF FWD WALL
.549 ± .014

2.069 ± .0015
+.272 ± .0010
2.341 ± .0025
−.549 ± .014
△10 1.792 ± .0165 INITIAL SPRING HGT

VI. BOLT HD CLR WITH ROTOR:

.2300 ± .0020
1.6310 ± .0030 CARTRIDGE LG
.8745 ± .0015 BOLT HD LG
−2.7356 ± .0065
2.7400 ± .0020 FG= TO LOCK
△11 .0045 ± .0085 CLR

VII. BOLT CLR WITH BARREL:

.0045 ± .0085 △11
1.0440 ± .0010 BOLT HD LG
1.6875 ± .0005 FG= TO BK OF BARREL
−2.7360 ± .0100
2.7400
△12 .0040 ± .0100 CLR

024-880 (9-69)

TECHNICAL ANALYSIS FORM

BY D. GLIDDEN CK. DATE 9 OCT 1969 REV.	GENERAL ELECTRIC	PAGE 5 OF 9 MODEL REPORT

TANGLESS BOLT TOLERANCE STUDY

VIII. TO FIND FOLLOWER TRAVEL WITH BOLT ASSEMBLED AGAINST LOCKING SHOULDER:

2.740 ±.002 [illegible] TO LOCKING SHOULDER
.2969 ±.0148 △2
1.045 ±.001 TO ℄ OF ROLLER
~ ±.0017 "e" SEE CALC. IV
.2495 ±.0005 ½ CAM ROLLER DIA
△7a 4.3314 ±.0200 [illegible] TO ROLLER
−4.0280 ±.0038 △8
△8a .3034 ±.0238 TRAVEL

IX. TO FIND BOLT HD CLR:

2.740 ±.002
−1.6875 ±.0005
1.0525 ±.0025
−1.0440 ±.0010
△13 .0085 ±.0035 CLR IN WELL

X. FIRING PIN FALL DISTANCE TO STRIKE ROUND:

.2295 ±.0015
−.1626 ±.0085 △8
−.0669 ±.0100
.1860 ±.0040
△14 .1191 ±.0140

TECHNICAL ANALYSIS FORM

BY D. GLIDDEN CK. DATE 9 OCT 1969 REV.	GENERAL ELECTRIC	PAGE 6 OF 9 MODEL 7.62MM REPORT

TANGLESS BOLT TOLERANCE STUDY

XI. FOLLOWER TRAVEL VS. BOLT GAP:

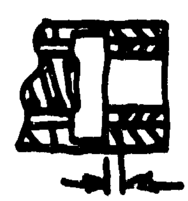
$$\begin{array}{r} .2969 \pm .0148 \triangle \\ -\ .2949 \pm .0233 \triangle \\ \hline .0020 \pm .0381 \end{array}$$

XII. CLEARANCE OF CROSS PIN & FIRING PIN SLOT:

$$\begin{array}{rl} .8745 \pm .0015 & \\ 1.3650 \pm .0020 & \\ .2480 \pm .0010 & \text{BODY SLOT} \\ \hline 2.4875 \pm .0045 & \\ -\ .1860 \pm .0040 & \\ \hline 2.3015 \pm .0085 = \text{"}f\text{"} & \text{SHOULDER TO HELIX} \end{array}$$

} BOLT @ SOLID HGT

$$\begin{array}{rl} 2.0690 \pm .0015 & \\ +\ .272 \quad \pm .0010 & \\ \hline 2.3410 \pm .0025 = \text{"}g\text{"} & \\ -\ 2.3015 \pm .0085 \ \text{"}f\text{"} & \text{(SEE ABOVE)} \\ \hline .0395 \pm .0110 & \text{CLR (BOLT @ SOLID HGT)} \end{array}$$



TO FIND CLR @ FALL OFF PT:

$$\triangle \ \frac{.2949 \pm .0233}{.00625/\text{DEG}} \approx \underset{= h}{47^\circ} \pm 2.4^\circ$$ POSSIBLE ROTATION DUE TO FOLLOWER

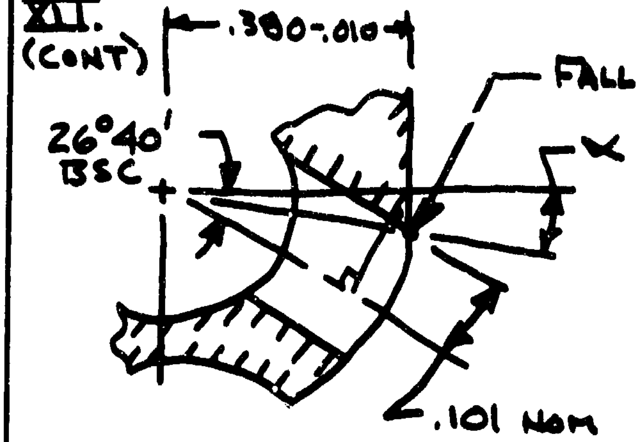
(CONT)

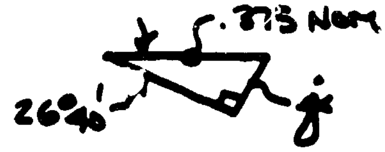
TECHNICAL ANALYSIS FORM

BY D. GLIDDEN CK. DATE 9 OCT 1969 REV.	GENERAL ELECTRIC	PAGE 7 OF 9 MODEL 7.62 MM REPORT

TANGLESS BOLT TOLERANCE STUDY

XII. (CONT)





$j = .375 \sin 26°40'$
$= .16830$

$k = j - .101 = .16830 - .101 = .06780$

k — $l = k \div \cos 26°40' = .07531$

$\alpha = \arctan(.07531 \div .375)$
$= 11°21' \approx 11.3°$

11.3° ℄ TO FALL OFF PT
30.0° COCKING SLOT
~ ±.25° BETWEEN PINS

$41.3° \pm .25° = n$ ROTATION NEEDED TO FIRE

47.0° ± 2.4° ROTATION VIA FOLLOWER TRAVEL
−41.3° ± .25° " TO FIRE

5.7° ± 2.65° ≈ .0356 ± .0166 GAP
+2.3015 ± .0085 f
−2.3371 ± .0251
2.3410 ± .0025 g
.0039 ± .0276 CLR

WITH BOLT @ FALL PT

TECHNICAL ANALYSIS FORM

BY D. GLIDDEN CK DATE 10 OCT 1969 REV	GENERAL ELECTRIC	PAGE 8 OF 9 MODEL 7.62 MM REPORT

TANGLESS BOLT TOLERANCE STUDY

XIII. To Find Distance From Apt Dwell To Gear:

8.032 ± .0025
− .498 ± .0008 FWD BRG
7.534 ± .0035
− .300 ± .0125
7.234 ± .0158 TO EDGE OF APT GEAR
= m

4.185 ± .003
− 4.094 ± .001
.091 ± .004
+ 2.3156 ± .0250
(18) 2.4066 ± .0290
+ 4.0940 ± .0010
6.5006 ± .0300

7.234 ± .0158 m
− 6.5006 ± .0300
(19) .7334 ± .0458

XIV. Rear Protrusion of Bolt Behind Roller:

1.840 ± .010 HD LG
− 1.045 ± .001 TO ℄ ROLLER
.795 ± .011
− .2495 ± .0005 ½ CAM ROLLER
(20) .5455 ± .0115

TECHNICAL ANALYSIS FORM

BY D. GLIDDEN CK DATE 10 OCT 1969 REV	GENERAL ELECTRIC	PAGE 9 OF 9 MODEL 7.62 MM REPORT

TANGLESS BOLT TOLERANCE STUDY

XV. SPRING COMPRESSION:

41.30° ±.25° ∡ (SEE CALC. XII)
×.00675
.2881 ±.0016
−.0948 ±.0222 (A) (AFT PIN CLR LOSS)
.1633 ±.0238
−.1625 ±.0085 (A)
.0008 ±.0323
−.0323
.0315 MAX FREE FALL OF PIN

XVI. FIRING PIN PROTRUSION BEYOND BOLT:

.2295 ±.0015
−.1860 ±.0040
.0435 ±.0055

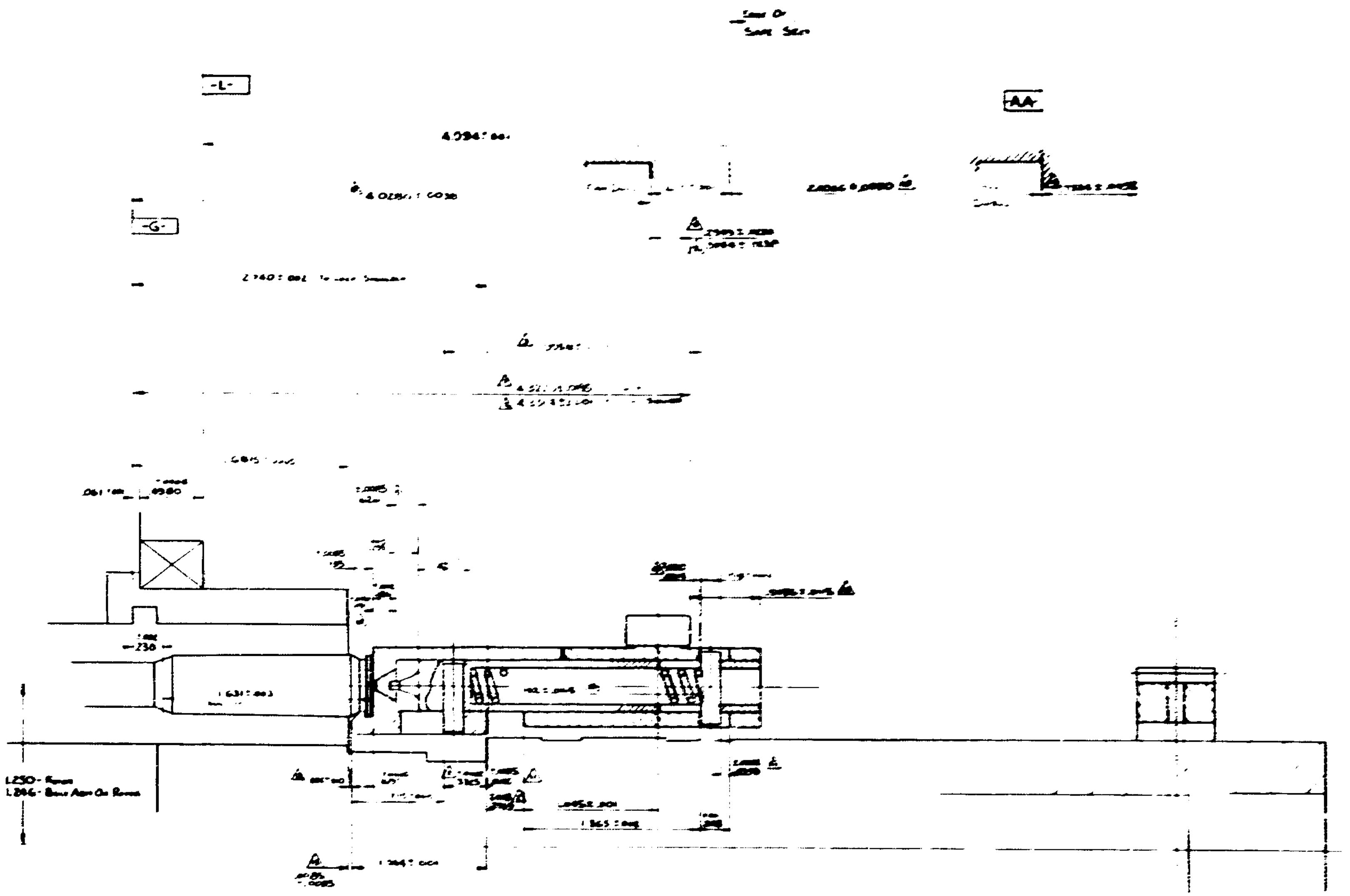


Figure 23. Tolerance Study Layout of Tangless Bolt

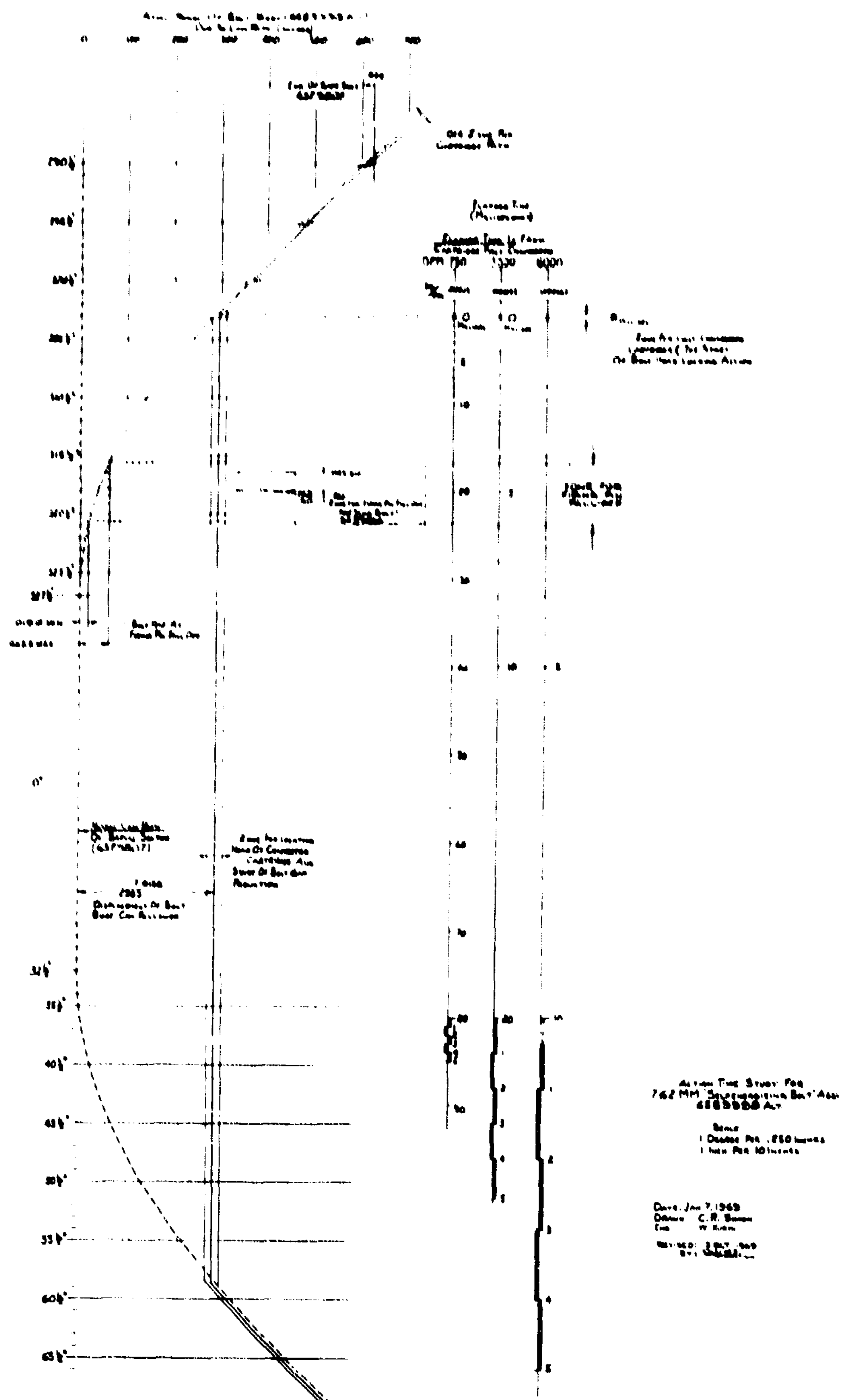


Figure 24. Action Time Study for Self-Actuating Bolt Assembly

SECTION II

MINIGUN CLUTCH, SCOPE ITEM 2

A. INTRODUCTION

The reasons for using a clutch as a means of ensuring a safe gun are not new to applications involving a multibarreled, Gattling-type gun. Economic considerations of operating the gun with other forms of clearing, increased effective payload, and improved safety are all well established needs justifying the use of a clutch.

A major difference between the clutch developed under this contract and previously developed clutches is that the new clutch is designed to be mounted within the aft end of the present 7.62-mm GAU 2B/A minigun rather than as an integral part of a feeder. Several major design problems were brought about by this placement of the clutch, but one major advantage was gained. By locating the clutch within the gun, it could be used with the several different types of feeders for all applications instead of requiring a unique, separately designed clutch for each application.

Another basic design criteria for this clutch was to design it in a configuration that could be supplied as a modification kit and installed on any gun in the field with no modification required to the gun housing or rotor.

B. METHOD OF OPERATION

1. Basic Operation

The underlying principle in the operation of the clutch as an instrument for clearing is that the feed system is disconnected from the gun and brought to a controlled stop. The gun continues to rotate and fires all of the ammunition remaining in the gun, thus ensuring a safe gun. To fire, the gun and feeder are automatically re-engaged in a timed position. The actuation of the clutch is governed by a solenoid in such a way that the gun will fire when the solenoid is electrically energized. Figures 43 through 49 show the minigun clutch.

2. Detailed Operation

Figure 49 shows an exploded view of the clutch assembly. During firing of the gun, the torque used to drive the feed system is transmitted from the gun rotor, which is driven by the main motor, to the rotor housing (11839384). The interior coutour of the rotor housing matches the contour of the aft end of the present gun rotor and transmits both gun feeder timing and torque from the rotor to two slots, which in turn drive the two interior lugs (driven lugs) on the gear actuator (11839378). These two driven lugs cause the entire gear actuator to rotate and transfer torque to the aft rotor spur gear (11839381) by means of the four large tongs which maintain a mesh with the four longitudinal slots on the inside diameter of the gear. This gear in turn drives the feed system. The new gear is no longer pinned to the gun rotor as it is in the present gun, but is now capable of rotating independently of the gun rotor. The axial location of the gear on the rotor is identical with the present gun. The timing between the feeder and gun is controlled by the above train of components. The importance of the timing between the gun and feeder in the round handoff area necessitates relatively close tolerances on the pertinent dimensions of these parts.

a. Firing Mode

In the firing mode the solenoid is energized (plunger retracted) which, through the yoke assembly, forces the two actuator arms (11839377) to the extreme forward portion of their travel. On the inside of each actuator arm is a camming knife which cams the rotating knife ring (11839379) forward or aft, depending on the location of the solenoid plunger. With the actuator arms in the forward fire position and the gun rotating, the actuator camming knives force the rotating knife ring toward the rear. This action causes the driven lugs on the gear actuator to mesh with the driving slots on the rotor housing. (There are two actuating knives in this clutch instead of the one found in most other clutch designs.) Due to severe space limitations, it was impossible to obtain a sufficient base on the rotating knife ring to allow an asymmetrical force to cam it fore and aft without causing the part to cock and bind. This introduced another problem in that with two knives it is possible, due to tolerances and cocking, for the knives to try to cam the rotating knife ring in both directions at the same time. This occurrence would cause a stoppage. To eliminate this possibility, one of the knives on the rotating knife ring was cut to a steeper angle, thus causing one knife to make the initial decision as to which way to cam while the other knife provided a symmetrical camming force once the decision was made. The rotating knife ring slides fore and aft in four longitudinal slots in the rotor housing. Contact is maintained between the rotor housing and the rotating knife ring; consequently, whenever the gun is rotating, the knife ring is also rotating.

The rotating knife ring is connected to the gear actuator by four lugs and the four 11839403 pins. This method of connection allows the rotating knife ring to rotate independent of the gear actuator; however, the two components translate fore and aft along the axis of the gun together. The gear actuator, like the rotating knife ring, slides axially in the aft rotor gear maintaining contact with it. Thus, these two parts always rotate or stop together.

b. Clearing Cycle

The solenoid is first de-energized when going into a clearing cycle. The return spring in the solenoid forces the plunger to the rear, which, through the yoke assembly, causes the two actuator arms to go to the rear also. The rotation of the rotating knife ring and the interference between it and the two actuator knives cams the rotating knife ring and, consequently, the gear actuator forward. The driven lugs on the gear actuator move forward, out of contact with the driving slots, and the four stopping lugs on the outside diameter of the gear actuator mesh with the four stopping slots in the clutch housing (11839376). The clutch housing is rigidly keyed to the gun housing through the bearing housing (11839374) and the finger on the solenoid mounting bracket (11839382). The meshing of the stopping lugs with the stopping slots brings the gear actuator and, consequently, the aft spur gear to an abrupt stop. (The gear actuator and the entire feed system are now completely independent of any gun rotor motion.) The feed system is stopped, and the rotor continues to rotate under power until clear of all remaining ammunition.

The angular location of the gear and the amount of time required for the feeder to come to a complete stop are extremely important. Once the gear actuator driven lugs lose contact with the rotor housing, no timing exists between the gun and feeder. Contact between two parts must be maintained until the bolt head has complete control of the last round to be fed (i.e., the last round fed is completely free of the feeder sprocket). Also, the feeder must be stopped before the feed system begins to feed the next round to the bolt head (i.e., the next round to be fed is completely clear of the bolt head). The time when the transition between the driving slots and stopping slots begins is dependent on the camming angle and total throw of the knives.

To fire the gun, the solenoid is energized, which moves the actuator arm to the forward position. At the same time, power is supplied to the motor, causing the rotor to turn. Since the rotating knife ring is still in the forward position (from the previous clearing cycle) and the actuator knives have moved to the forward position, an interference exists which causes the rotating knife ring to cam aft under the power of the gun motor. This action takes the stopping lugs of the gear actuator out of contact with the stopping slots and meshes the driven lugs with the driving slots on the rotor housing. Timing is also important in this transition, since it is imperative that the two driven lugs be in a location which enables them to mesh with the driving slots.

There are four stopping lugs, but only two driven lugs. This is due to the generally higher loads encountered in stopping the entire feed system. The fact that there are four stopping lugs implies that the gear can be stopped in one of four positions, each 90 degrees out of phase. However, a 90-degree phase shift would produce a corresponding shift of 90 degrees when the clutch was reactivated to fire, and no driving slots would be available to mesh with the driven lugs. Also, during firing and normal flight, recoil and "g" forces could cause the gear actuator to translate fore and aft. For these reasons, the knives on the rotating knife ring have been lengthened to include approximately 90 degrees of arc. This allows the gear actuator to move fore or aft only when the solenoid is energized or de-energized.

c. Power Loading

Although no present Army systems require the ability to power load, several Air Force systems do have this requirement. Since it is conceivable that such an ability will eventually be required by the Army, it has been included on the clutch.

In order to power load, the clutch must first be engaged. This can be accomplished by manually engaging the solenoid and rotating the gun in the firing direction until the feeder begins to rotate (approximately one-half revolution of the gun). With the solenoid still manually depressed, the power load will now operate. Depressing the solenoid and rotating the gun cams the gear actuator into engagement with the rotor housing (see Figure 25). The gun is then rotated in the direction opposite to the firing direction, and the driven lugs on the gear actuator are driven by the power loading driving surface of the rotor housing.

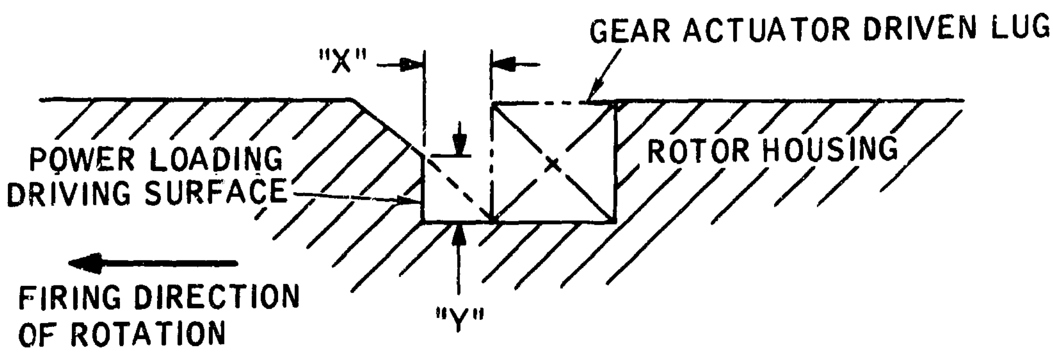


Figure 25. Power Loading

It was experimentally determined that the minimum height ("Y") required for the power loading driving surface was 0.095 inch. The angular cut intersecting the 0.095-inch surface is a clearance cut which allows the driven lugs to enter the driving slot on the camming angle of the knives. The dimension "X" shown on the sketch is the clearance resulting from the addition of the power loading step. This increased clearance allows an additional movement of the gear actuator, and consequently of the entire feed system, equivalent to one tooth of rotation in the aft rotor gear. This clearance was incorporated in such a way to avoid a late feed. The possibility of an early feed could occur only if the feed system rotated faster than the gun (e.g., if the gun would receive a high momentary torque which slowed it down slightly). If the feed were too early, the feed system would pause slightly (since it would not be driven at that time) until timing was again correct. No problems were encountered during any testing due to this possible cause.

C. TESTING

1. Clutch Unit 1

Dry firing on a MXU-470 Module System was started on April 13, 1969; 356 actuations were completed. This dry firing included cycling with up to 1500 rounds in the module drum at rates of 2000 and 4000 spm. Live fire testing was conducted at the Underhill Firing Range from July 7 to July 11, 1969. A total of 50,000 rounds were fired using the clutch; approximately 26,000 rounds were fired using the Module System; 22,500 rounds were fired using a delinking feeder; and 1500 rounds were fired using a Pod System. The equivalent rounds fired was 85,000 based on the 100 rounds per burst or 883 actuations.

One problem encountered early in this portion of the testing resulted in a failure to start. When the feed system stopped at the end of a burst with the stopping lugs on the gear actuator in the extreme rear position in the stopping lug slots in the clutch housing, the driven lugs missed meshing with the driven lug slots upon start-up, causing the system to jam. To eliminate this problem, approximately 0.120 inch of material was added to the rear portion of the stopping lug slot in two of the four positions. After the addition of this material, it was impossible to duplicate this type of stoppage.

Another major problem that became apparent during live testing was: insufficient clearance had been allowed between the two sets of camming knives to eliminate the possibility of the two knives being caught halfway through an operation with one knife attempting to cam in the fire direction while the other knife attempted to cam in the clearing direction. To eliminate this problem, the camming angle on the non-decision knife was increased to allow for additional clearance. Now when the decision knife of the rotating knife ring is lined up edge-to-edge with the actuating knife there is 0.070 to 0.080-inch clearance between the edges of the two knives (see Figure 48). After the clearance was increased, there were no further stoppages attributed to this cause during this portion of the test. Detailed live firing data sheets are included in Appendix II-C.

After testing and modification had been completed on the first clutch, the major unresolved problem was the inability of the clutch to perform a power load operation satisfactorily.

In order to power load, first the loading sector must be installed; then the clutch solenoid must be mechanically locked in the energized position; and finally the gun must be hand rotated approximately one-half revolution in the firing direction to engage the gun to the feeder. The system is now ready to be power loaded.

The ability to drive the feeder in reverse was initially dependent on a 0.040-inch step in the lead end of the driving lug slot in the rotor housing (11839384). During power loading, the rotor housing transfers power through this step to the gear actuator, which in turn drives the feed system in reverse. Test results and a tolerance study of the area involved confirmed the fact that under extreme conditions and severe vibration it was possible for the driving lugs to slip beyond the step and cam forward on the relief cut -- causing a stoppage. To eliminate this problem, material was removed from the power load drive side of the rotor housing. This shortened the lead-in and increased the power load driving surface to 0.095 inch. There were no further stoppages in testing with the revised configuration. Over 100 cycles have been run without ammunition and 6000 rounds have been loaded on an A37 system with no malfunctions.

2. Clutch Unit 2

Live fire testing was conducted at the Underhill Firing Range and the G.E.Springfield Range. A total of 100,100 rounds, representing 884 actuations, were fired on clutch unit 2. During this test, over 40,000 rounds were fired using the side-stripping feeder. No interface problems between the clutch and feeder were encountered. The remaining rounds were fired using a delinking feeder.

During testing, a stoppage which appeared to be the result of a burr on the rotor housing occurred. One of the four arms of the rotating knife ring appeared to hang up during transition from the forward to the aft (fire) position. This caused the part to cock severely and resulted in a failure to fire. To eliminate any future stoppages of this nature, these four arms will be lengthened by approximately 0.060 inch, on the third and fourth units, until they are flush with the rear portion of the rotating knife ring. This change yields better control of the rotating knife ring and greatly simplifies the configuration of the part. The slots on the rotor housing that receive these arms will likewise be modified.

To help ensure maximum engagement of the driven lugs during firing and power loading, 0.030 inch of material was added to the forward end of the actuator arms. This change forces the rotating knife ring, and consequently the driven lugs, to seat approximately 0.030 inch deeper in the rotor housing. Testing of the revised configuration revealed a greatly improved operation, especially during power loading.

The pins which connect the solenoid mounting bracket to the bearing housing are another potential problem. During a severe stoppage it is possible for the solenoid mounting bracket to tip. This tipping allows the finger on the bracket which attaches to the gun housing cover lugs to jump position and rotate. This type of stoppage requires the clutch to be reassembled and the connecting pins replaced. The upgrading of these pins from the present roll to a spiral pin should eliminate any possibility of the solenoid bracket's tipping as the result of a stoppage.

During handling, the pivot arm which connects to the solenoid plunger was bent slightly due to a hammer blow's making it asymmetrical. When the arm was assembled one way, this bend made it possible for the solenoid plunger to stick and cause a stoppage. By reversing the pivot arm, no more difficulties of this nature were encountered.

Three stoppages were experienced in which the two actuator knives attempted to cam the rotating knife ring in opposite directions. The first of these stoppages occurred due to a failure of one of the yoke support spring pins. The pin had been damaged during a previous stoppage and fell out during this burst. The stoppage occurred when the yoke could no longer control the axial movement of the actuator arms. The other two stoppages were caused by a combination of two factors. During the first stoppage, the clearance between the decision knife and the following knife was reduced to

0.048 inch. Also, the four arms on the rotating knife were prone to cocking slightly due to the small minimum engagement when in the forward position. (This has been corrected on all new parts.) After the knives were resharpened and the clearance increased from 0.048 to 0.078 inch, no further stoppages of this nature were encountered.

Several stoppages were experienced during continued testing of the second unit due to a failure of the mechanical joint between the solenoid mounting bracket and the bearing housing. A detailed investigation revealed the connector holes on the solenoid bracket had been damaged and were oversize. The stoppages were minimized by using a screw and nut instead of a pin to hold the parts together. There was some difficulty in keeping the screws tight. In production quantities these parts will be made as one piece, thus eliminating this potential problem.

D. INSTALLATION PROCEDURE

The clutch can be provided as a modification kit to be installed in the field on an existing gun. The procedure for installation of the clutch is as follows:

1. Remove the gun bolt assemblies and guide bar.
2. Remove the three bolts in the aft support.
3. Remove the rotor from the gun housing.
4. Drive the pins from the aft rotor gear and remove the aft gear and aft bearing.

A P P E N D I X II-A

Drawings

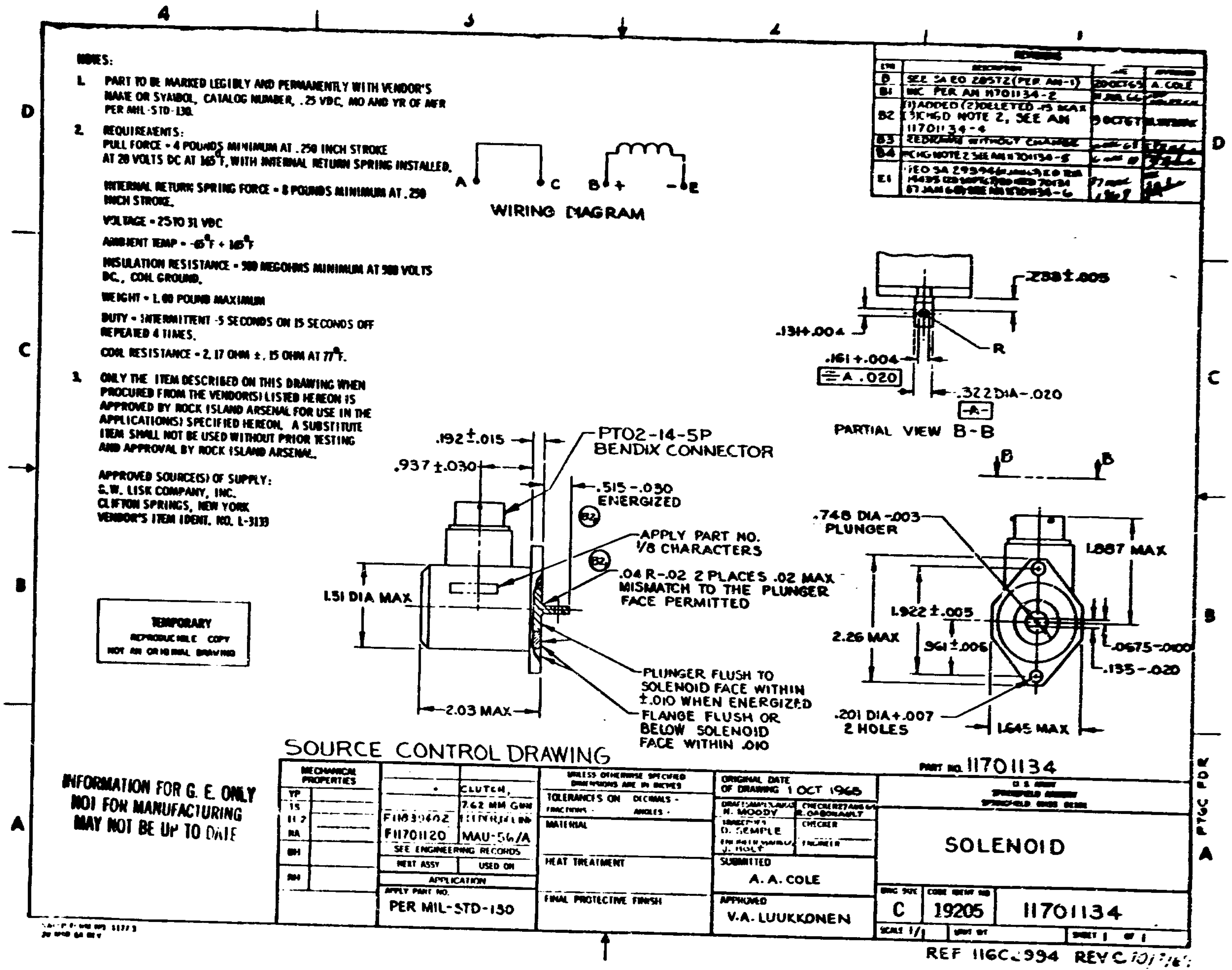


Figure 26. Solenoid

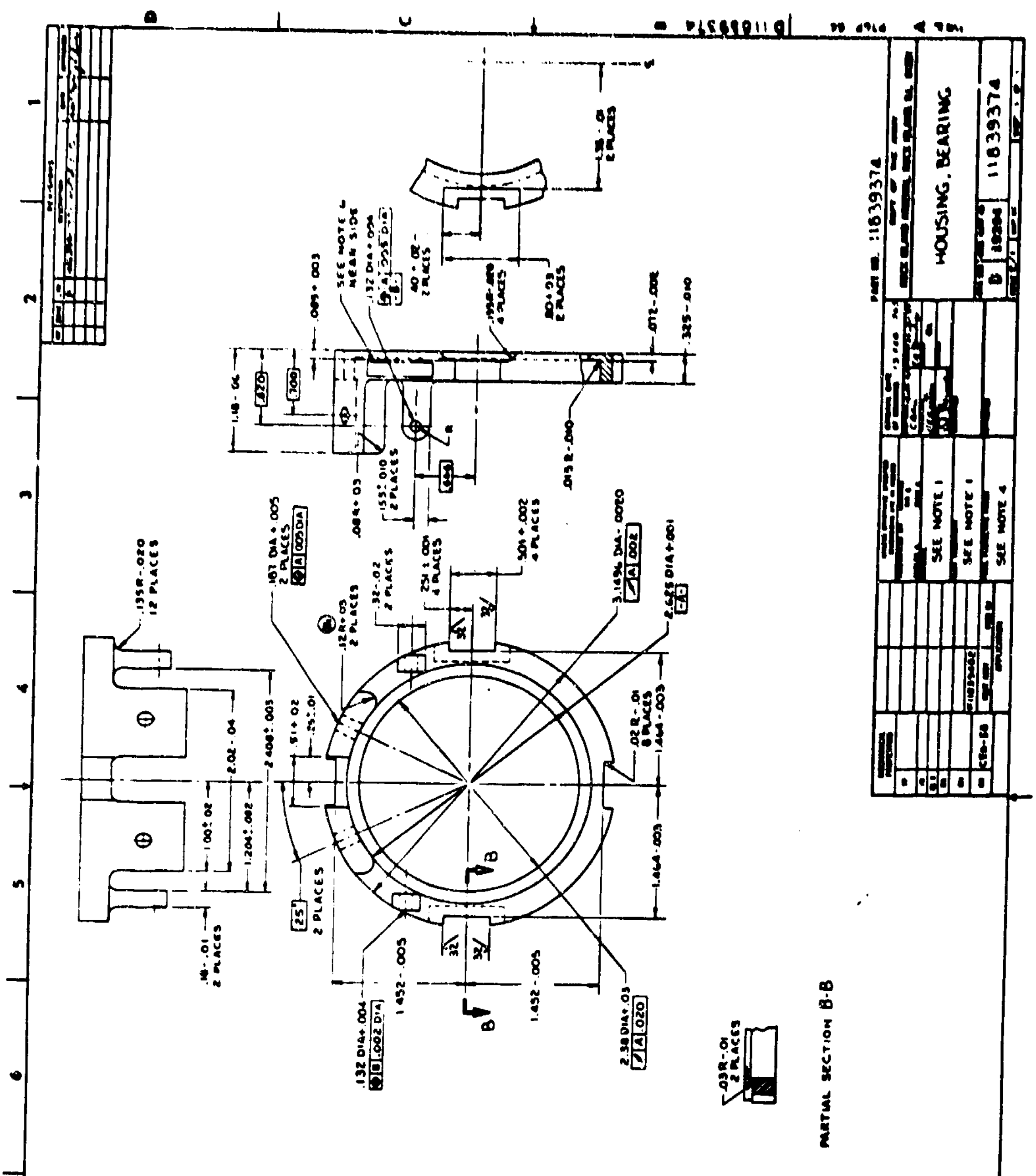


Figure 27. Bearing Housing

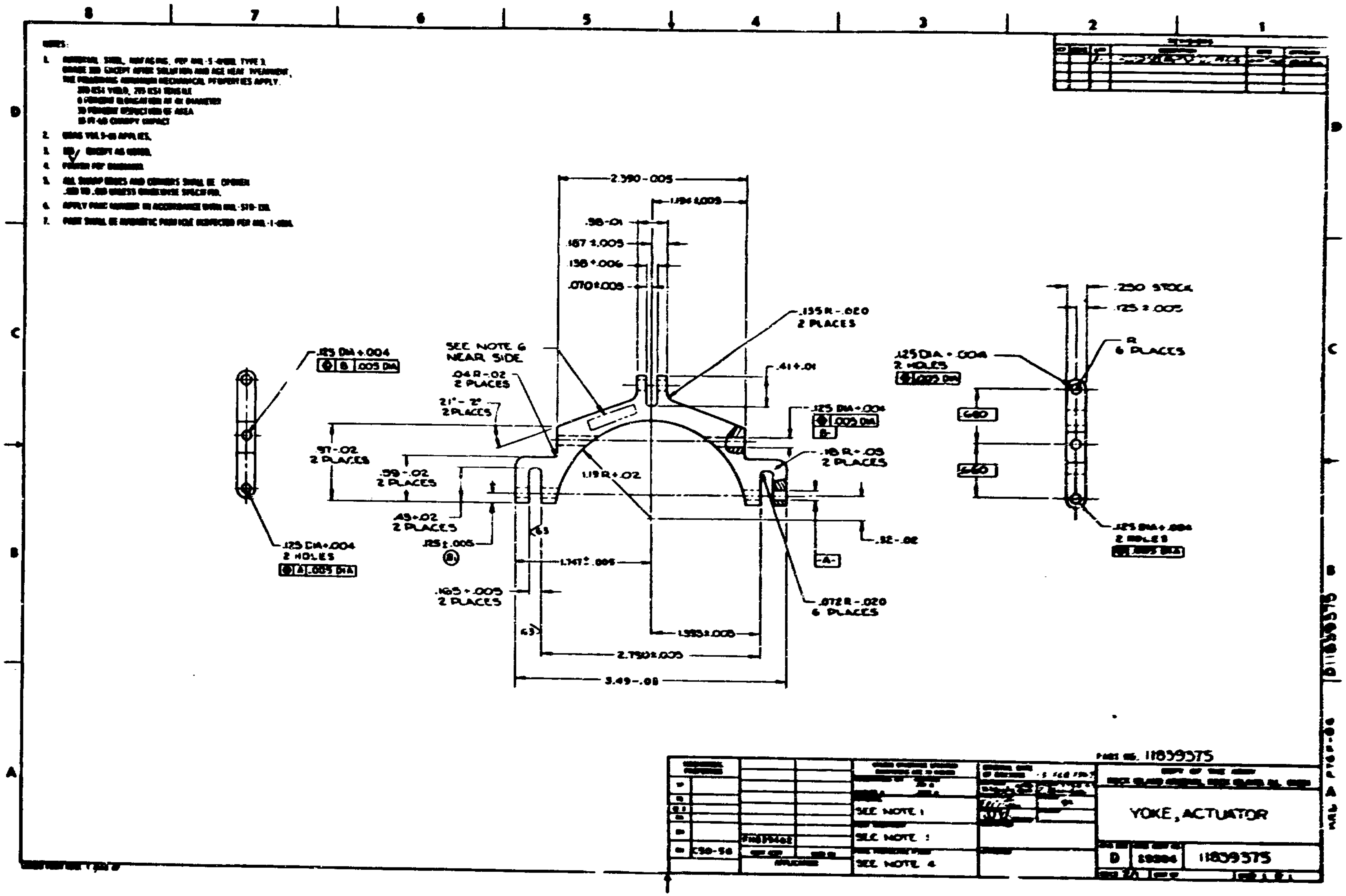


Figure 28. Actuator Yoke

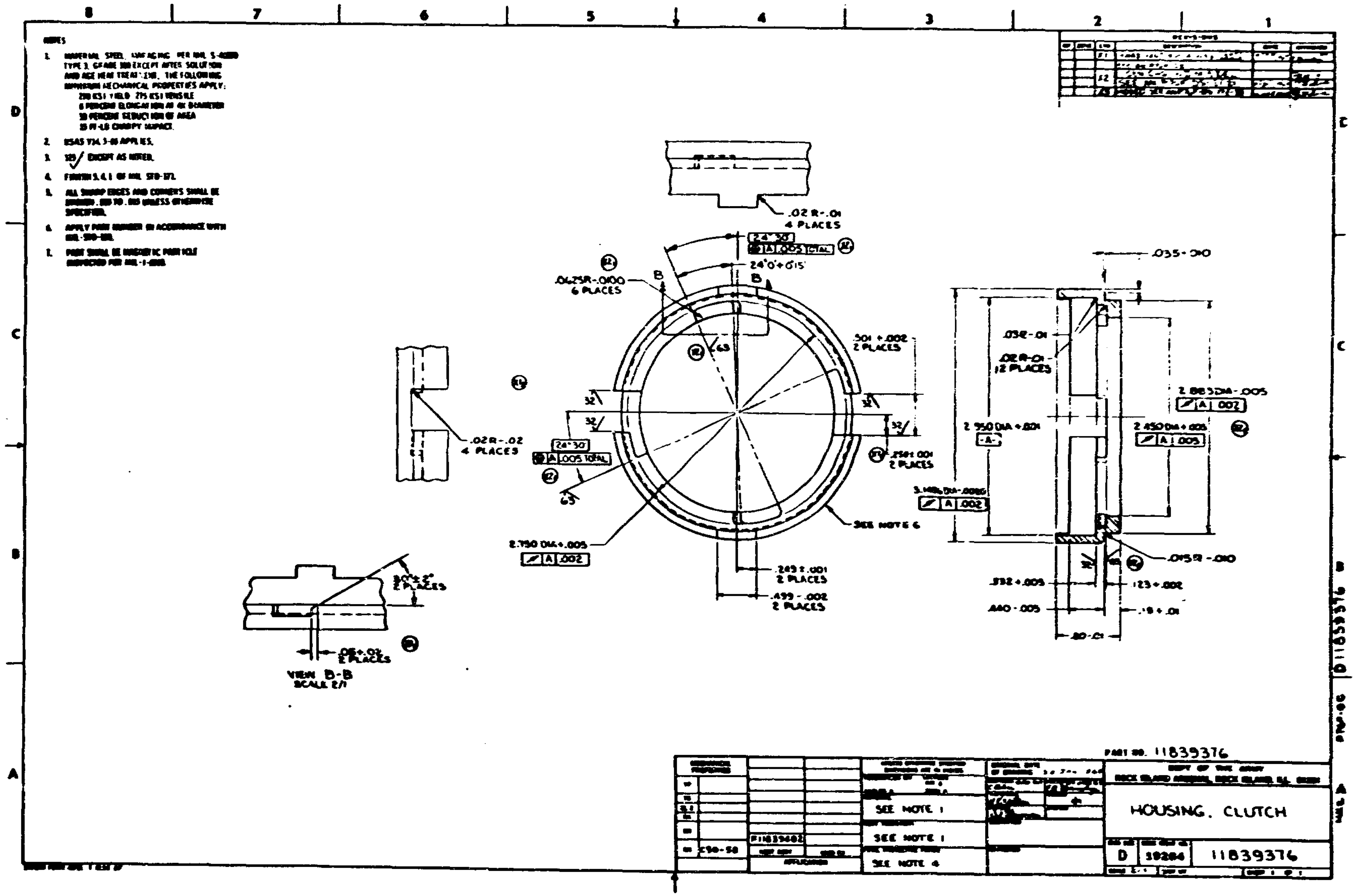


Figure 29. Clutch Housing

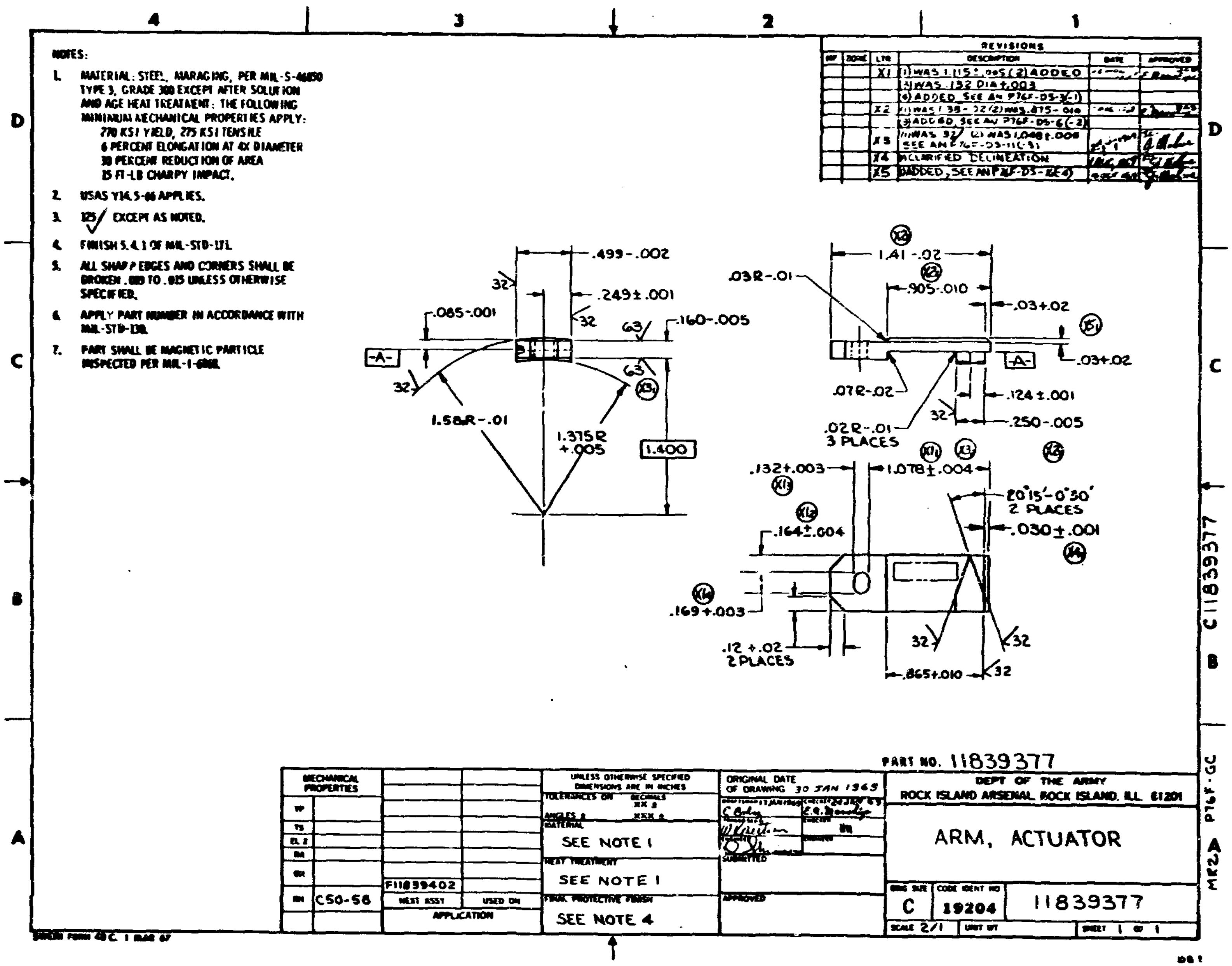


Figure 30. Actuator Arm

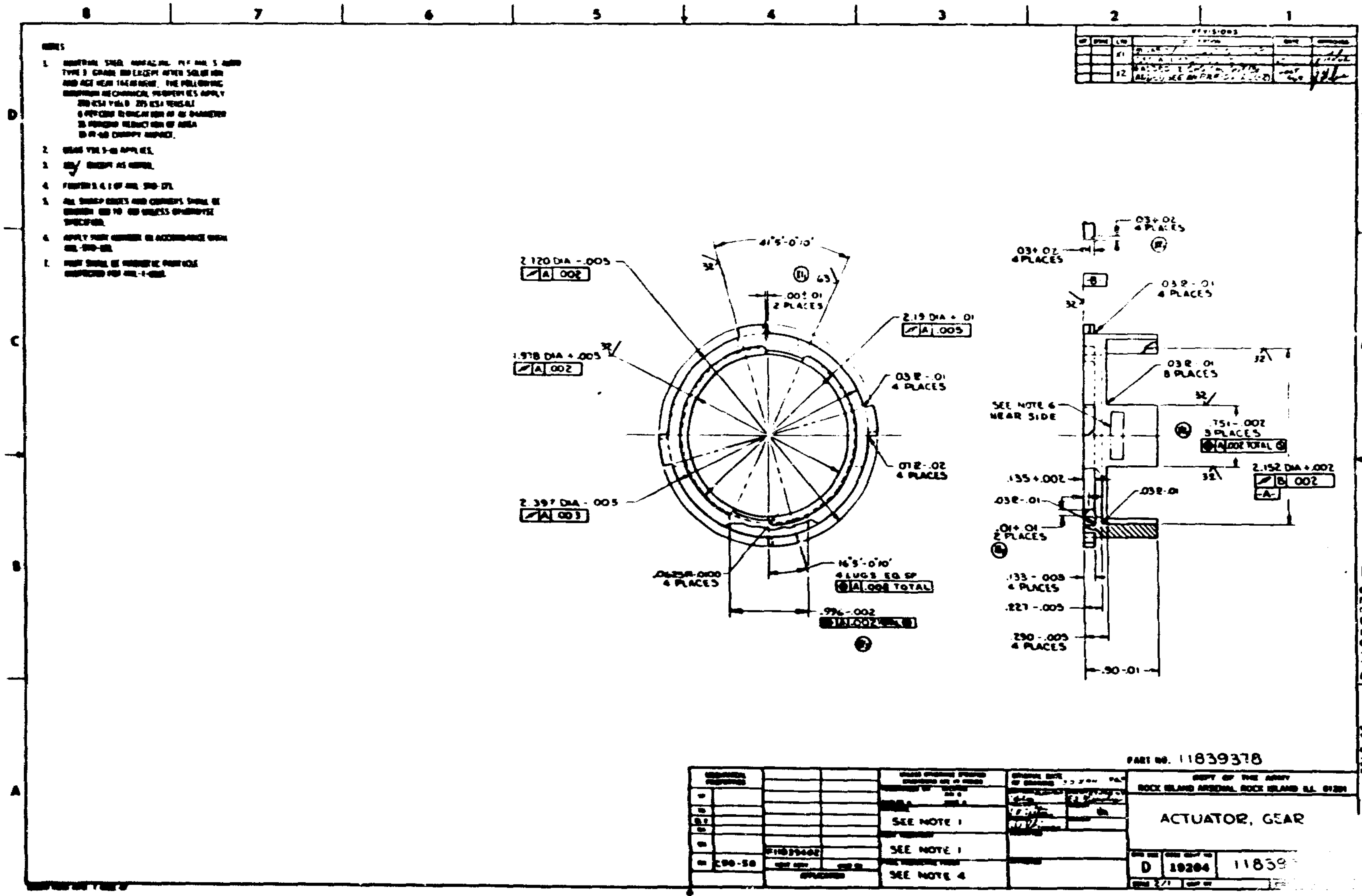


Figure 31. Gear Actuator

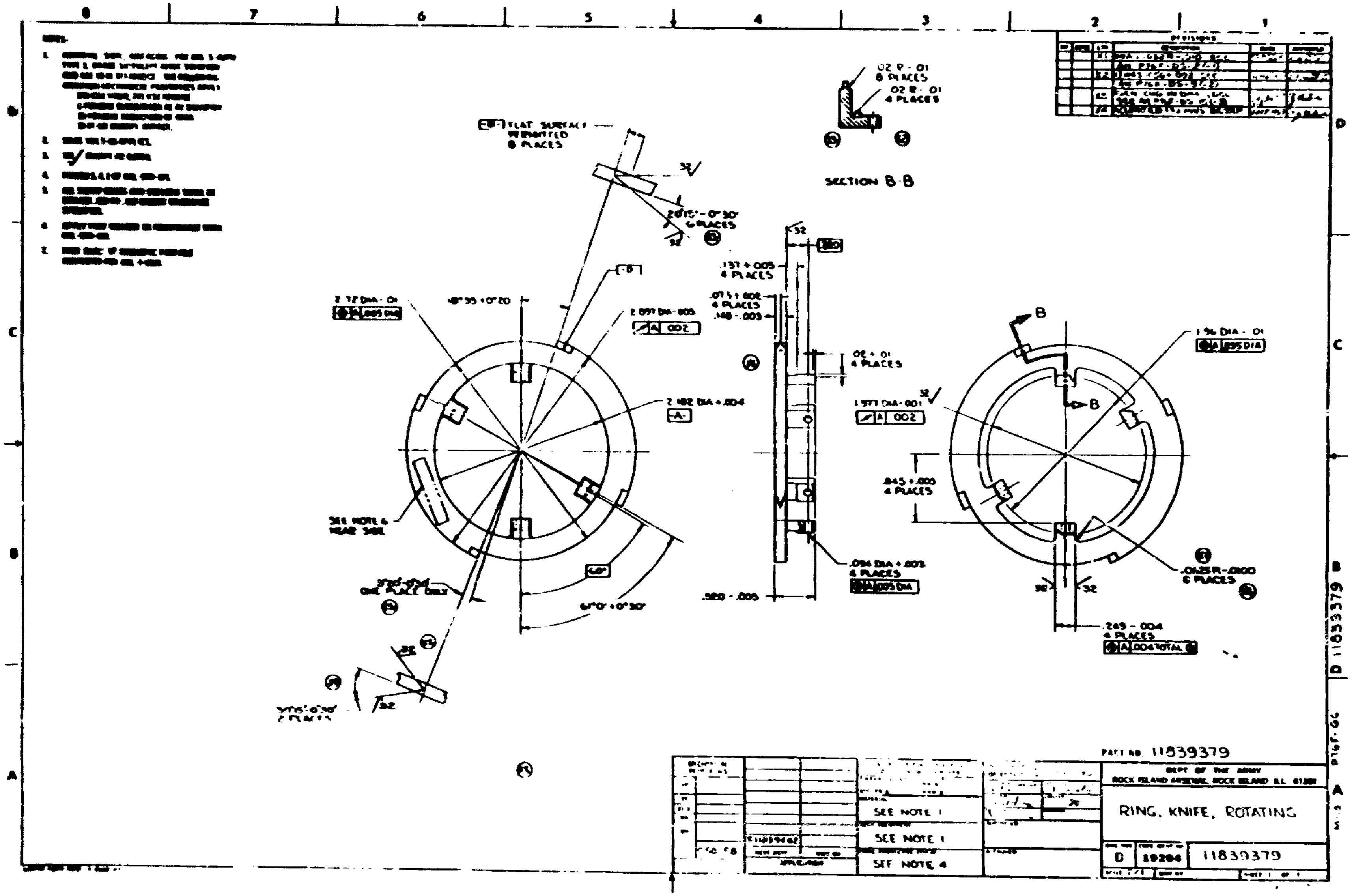


Figure 32. Rotating Knife Ring

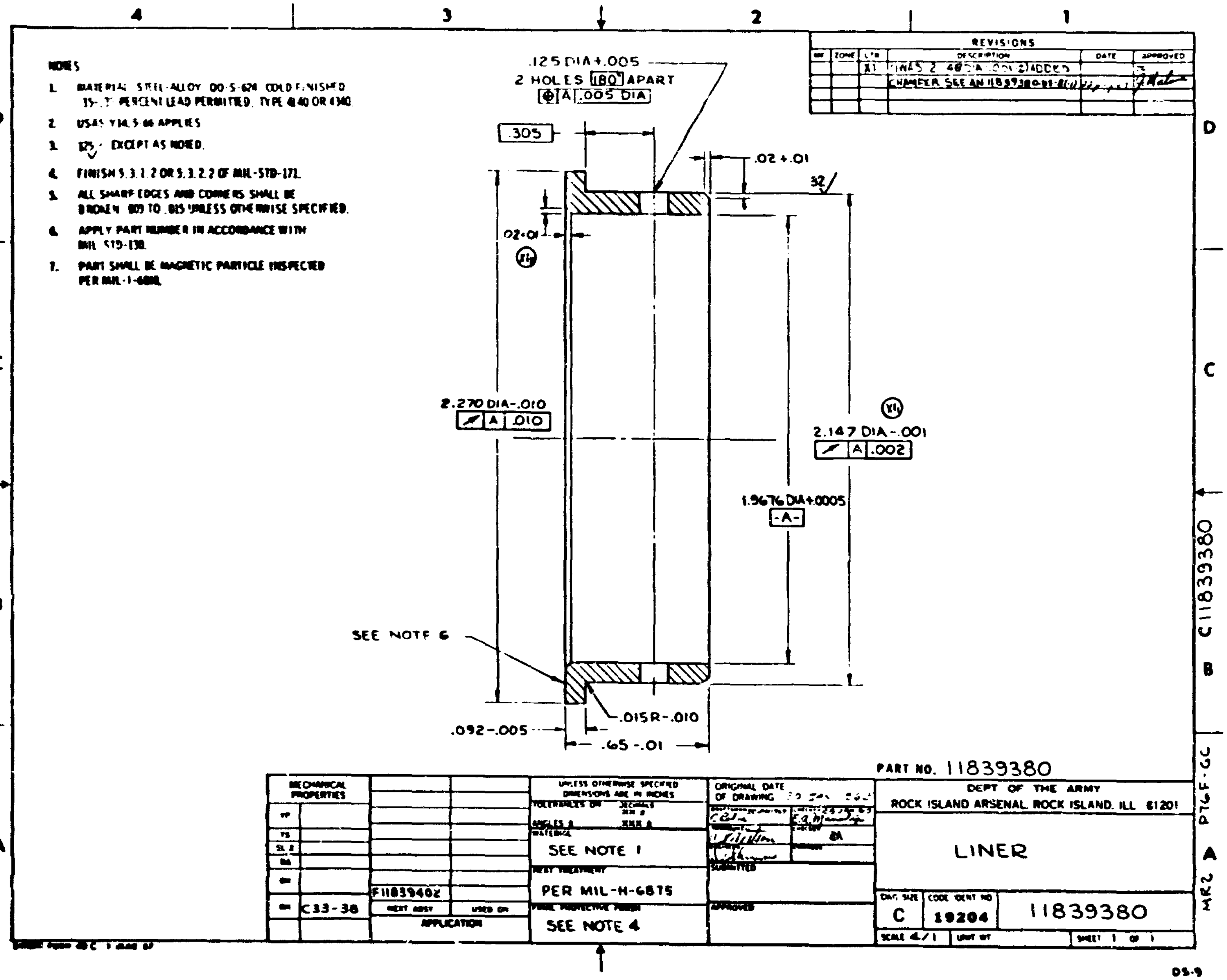


Figure 33. Liner

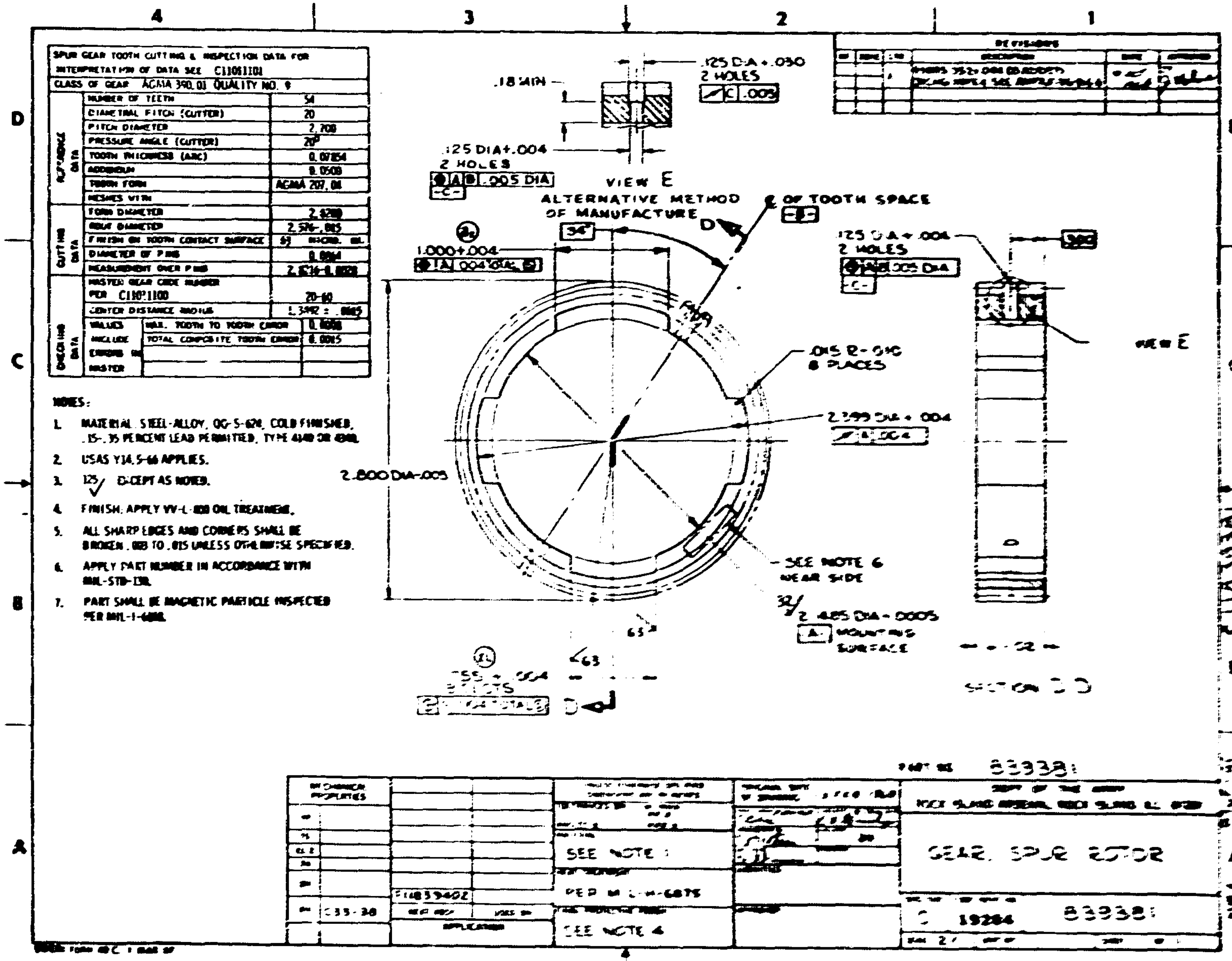


Figure 34. Rotor Spur Gear

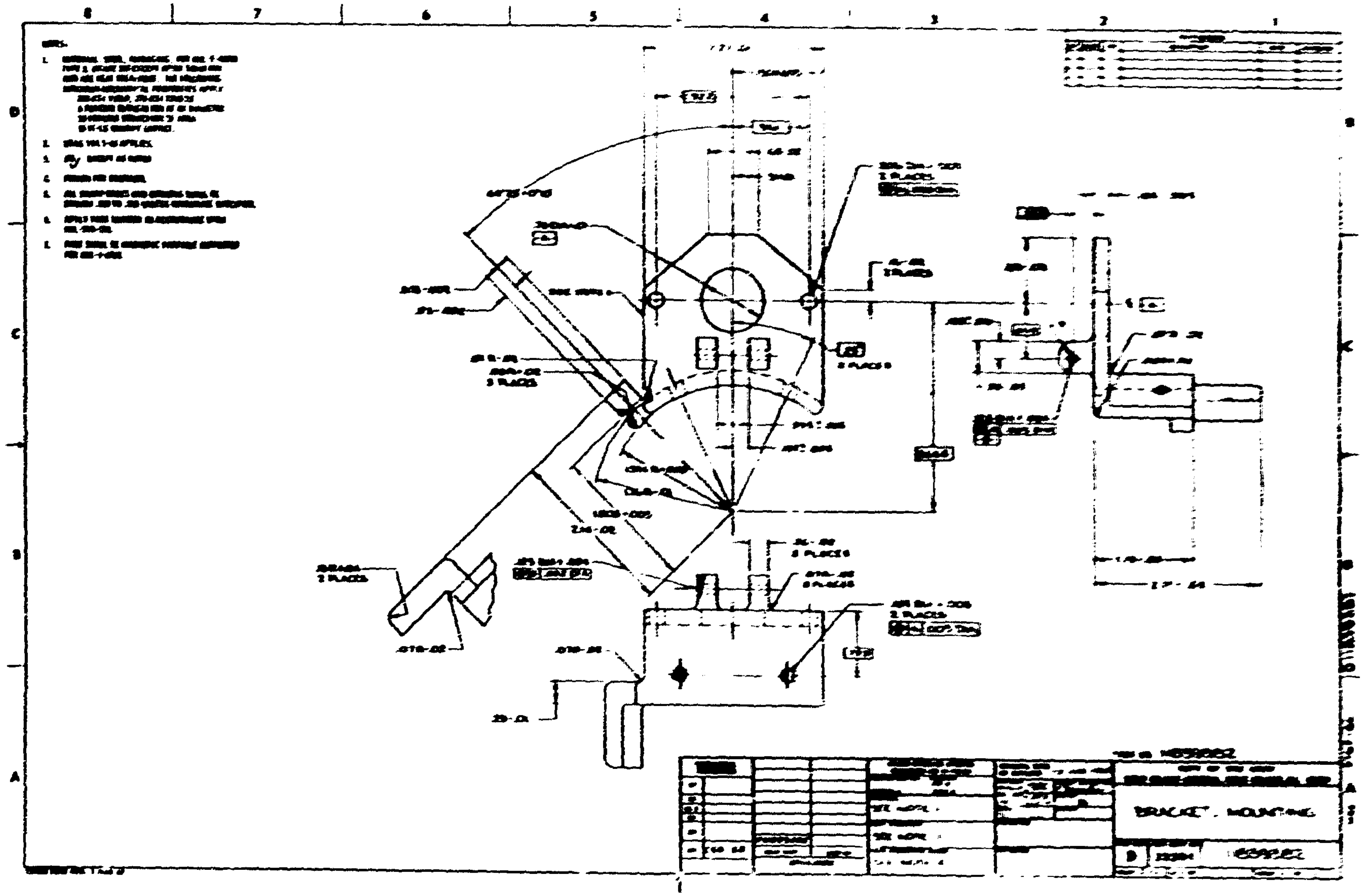


Figure 35. Mounting Bracket

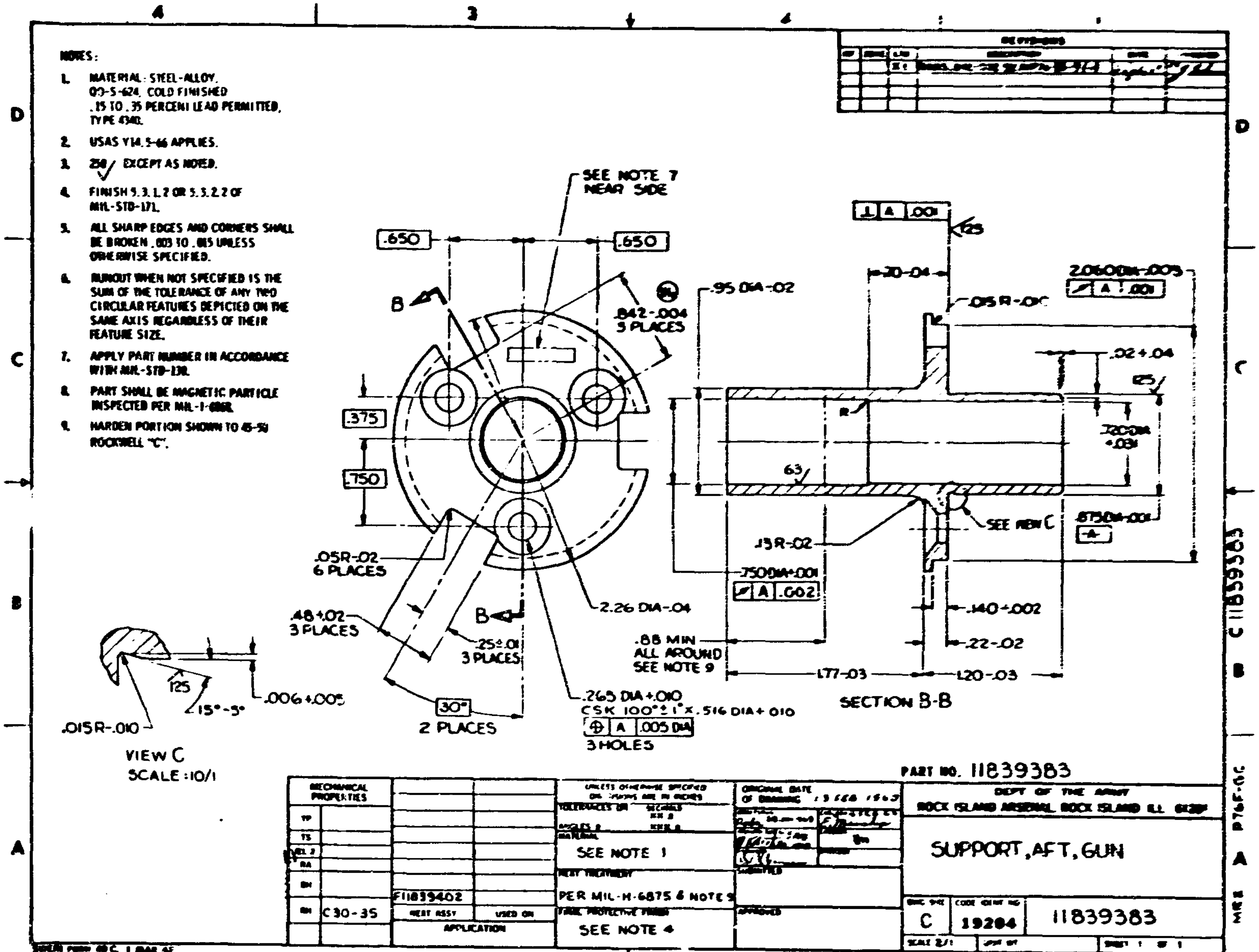


Figure 36. Aft Gun Support

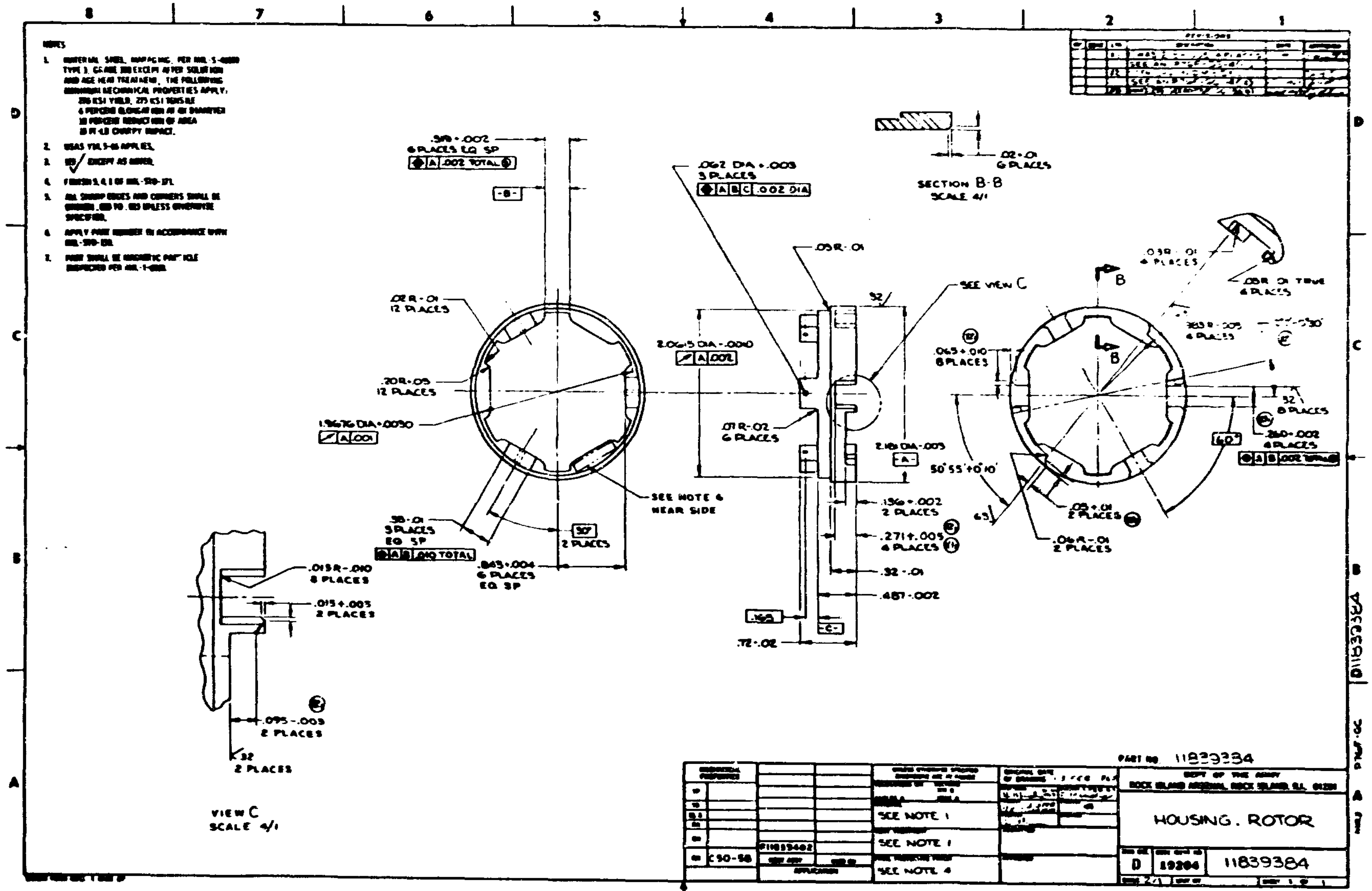


Figure 37. Rotor Housing

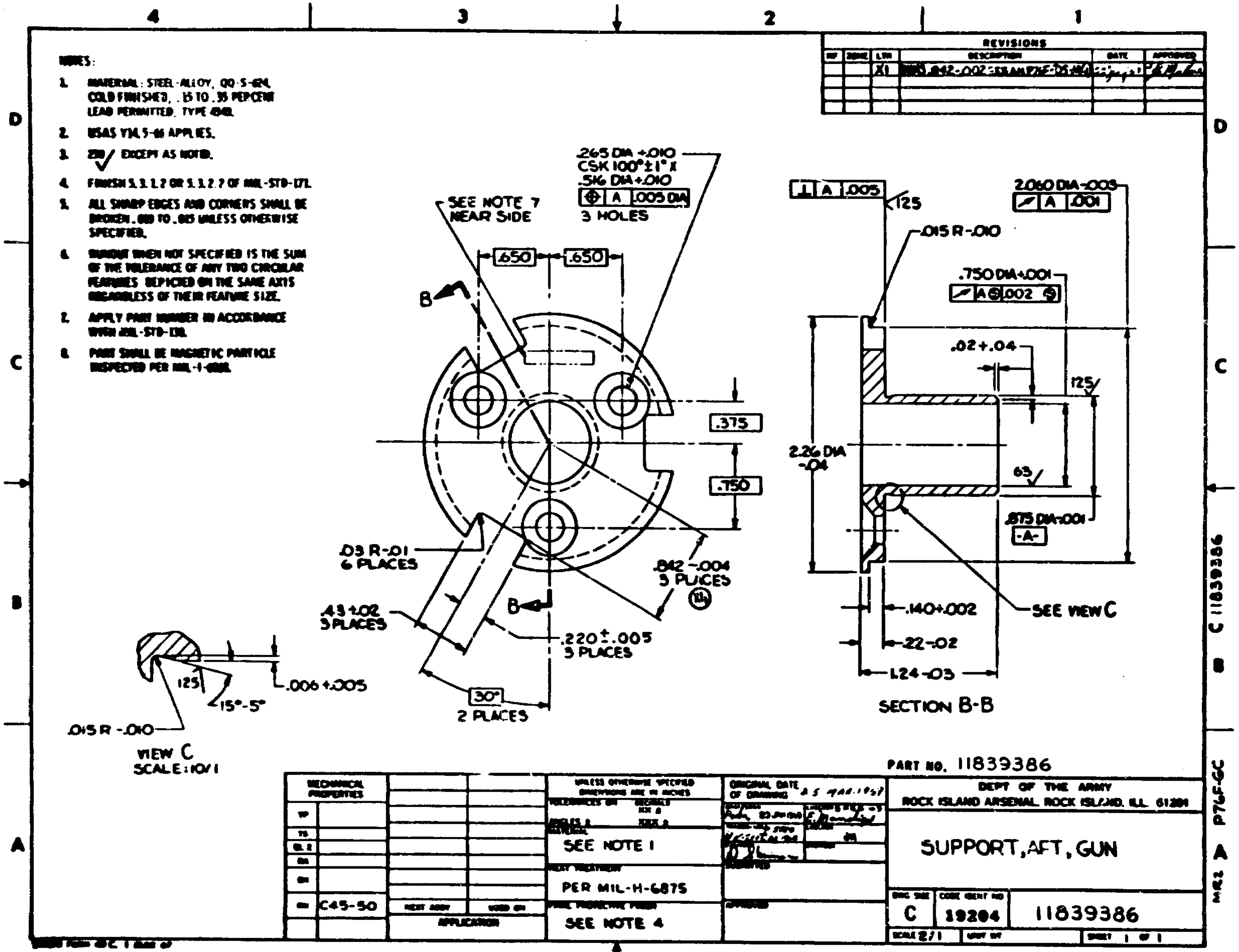


Figure 38. Aft Gun Support

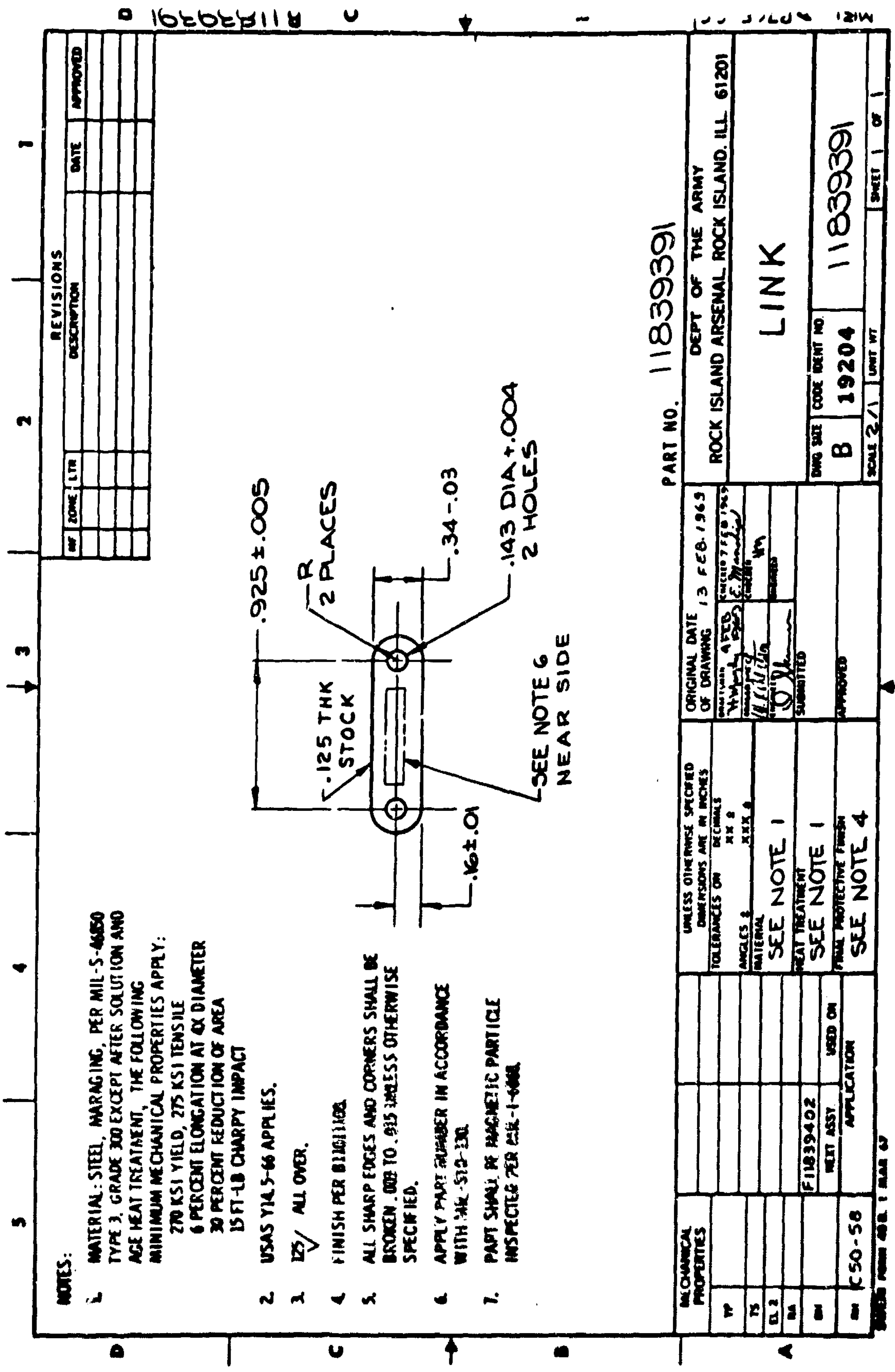


Figure 39. Link

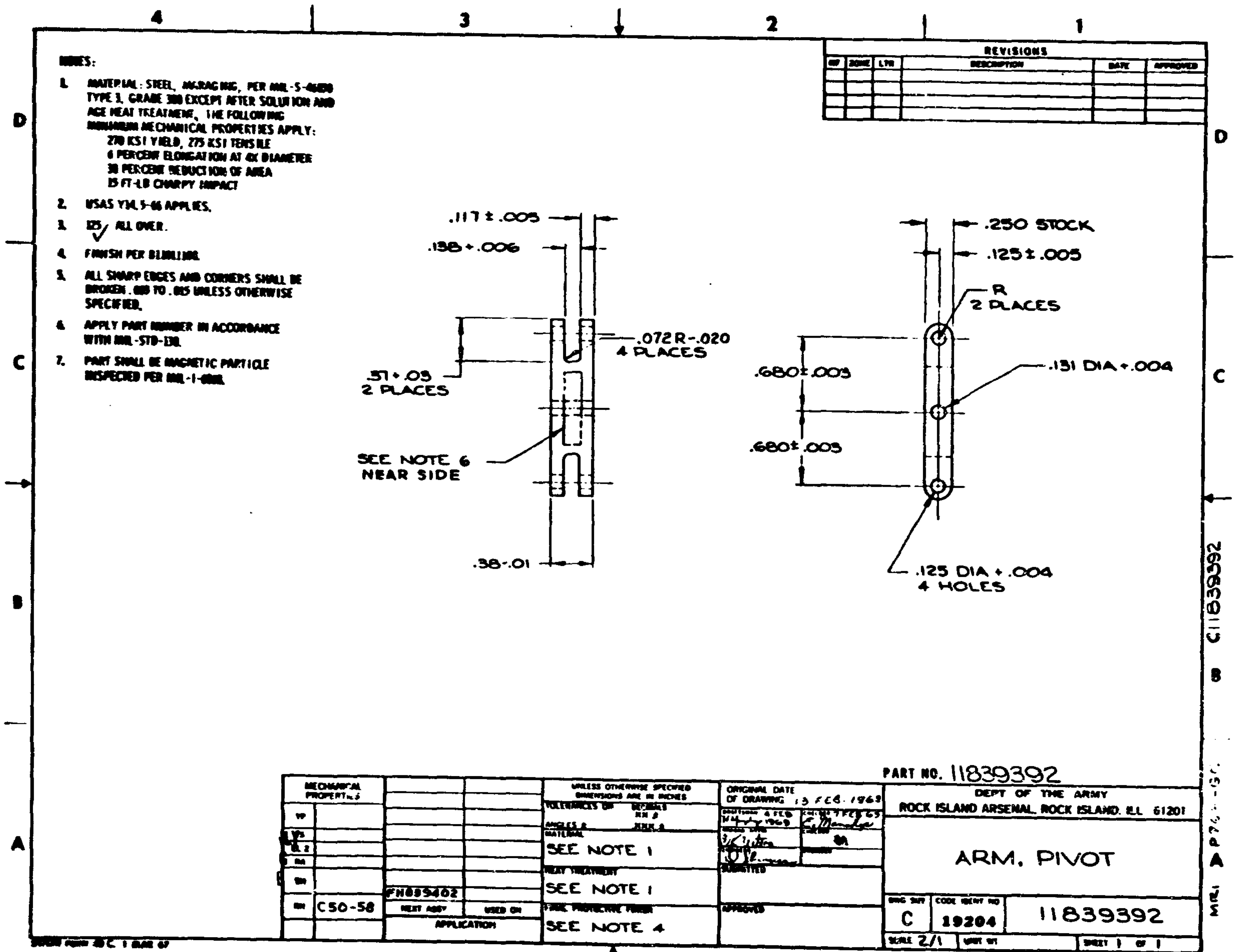


Figure 40. Pivot Arm

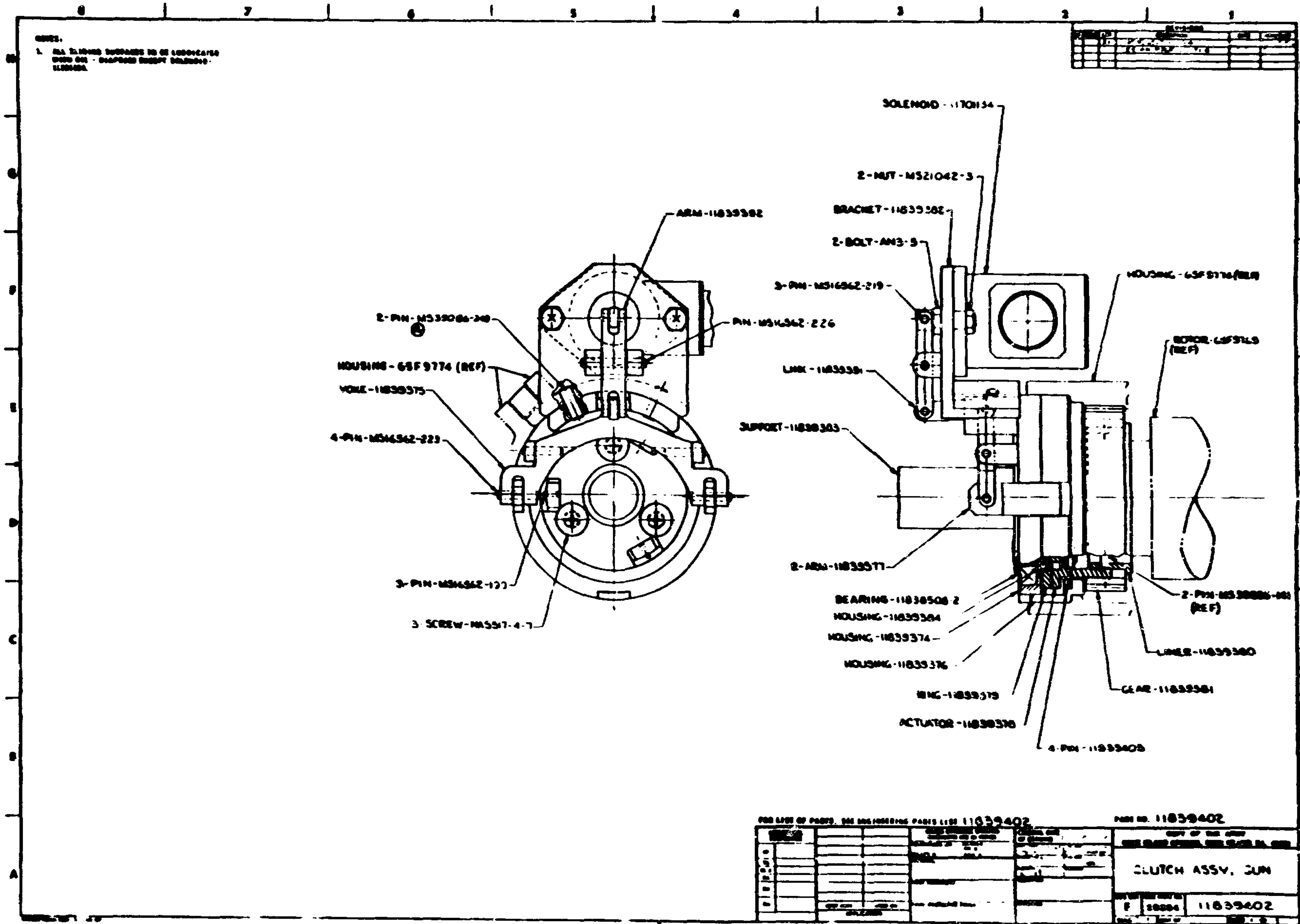
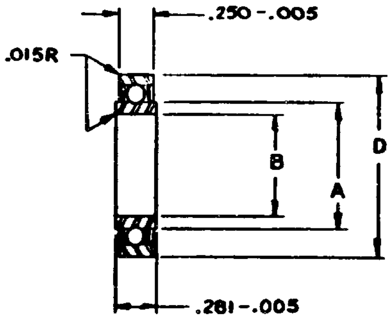


Figure 41. Clutch Assembly

NOTES:

1. MATERIAL: STEEL
2. SEAL CONSTRUCTION: SOFT SYNTHETIC RUBBER WITH STEEL CORE.
3. SEAL OPERATING RANGE, 225°F TO -65°F.
4. PART TO BE MARKED LEGIBLY WITH VENDOR'S NAME OR SYMBOL AND HIS CATALOG NUMBER PER MIL-STD-130.



PART NO.	VENDOR IDENT	B DIA	A DIA (REF)	D DIA
11838508	B546ZZ	2.3125 ± .0010	2.500	2.8750 -.0015
11838508-2	B545ZZ	2.0625 ± .0010	2.197	2.6250 -.0015

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	X1	PART NO. 2 ADDED		

SUGGESTED SOURCE OF SUPPLY:
MARLIN ROCKWELL CORPORATION
JAMESTOWN, NEW YORK

VENDOR ITEM IDENTIFICATION:
SEE TABLE

SPECIFICATION CONTROL DRAWING

PART NO. SEE TABLE

DEPT OF THE ARMY
ROCK ISLAND ARSENAL, ROCK ISLAND, ILL. 61201

BEARING, BALL
AIRFRAME

DWG SIZE	CODE IDENT NO	
C	19204	11838508

SCALE NONE | UNIT WT | SHEET 1 OF 1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
MATERIAL: SEE NOTE 1
HEAT TREATMENT
FINAL PROTECTIVE FINISH

ORIGINAL DATE OF DRAWING 23 OCT 1968

MECHANICAL PROPERTIES

NEXT ASSY	USED ON
	CLUTCH,
	7.62 MM GUN
	GUN, 20MM
F11839402	AUTO: XM197

APPLICATION

FSC-GE 3130 11

C11838508

XM197 FDR

Figure 42. Ball Bearing

A P P E N D I X II-B

Photos and Illustrations

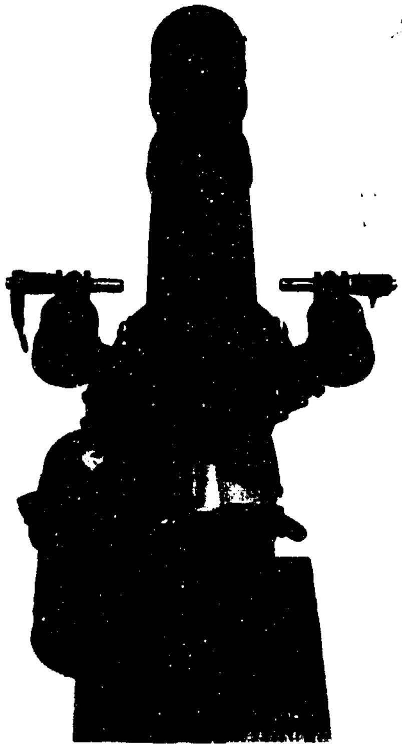


Figure 43. Clutch Assembly on Minigun (Rear View)

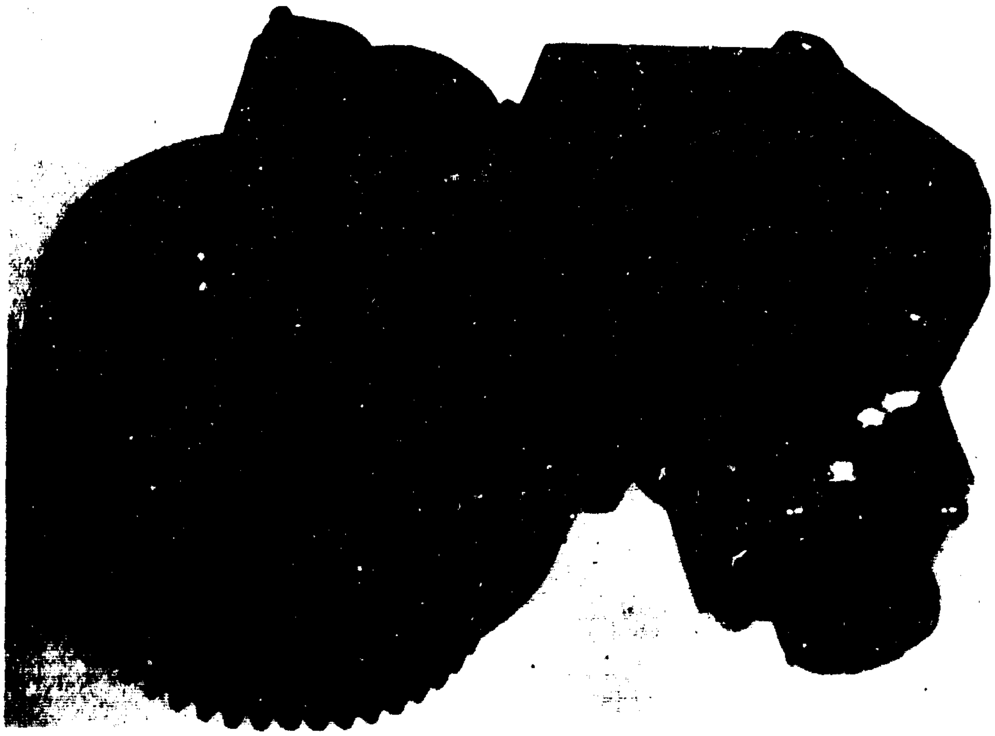


Figure 44. Clutch Assembly (Rear View)

Figure 45. Clutch Assembly (Front View)

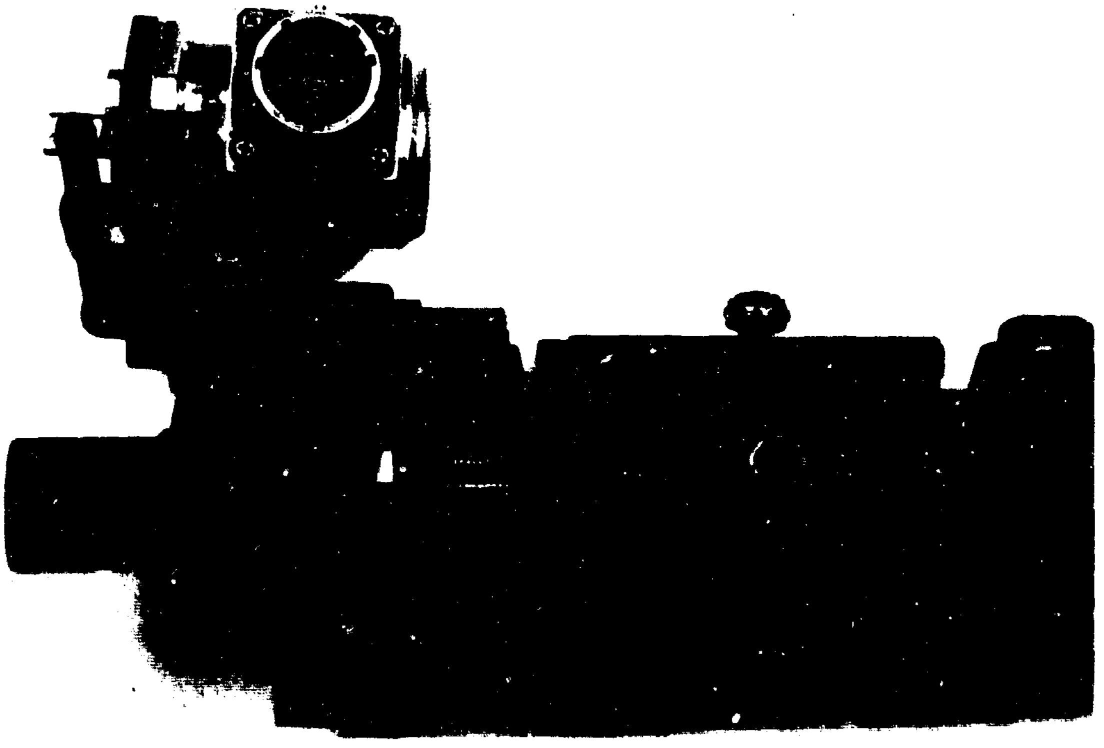


Figure 46. Clutch Assembly Mounted on Gun Rotor (Side View)

Figure 47. Clutch Assembly Mounted on Gun Rotor (Rear View)

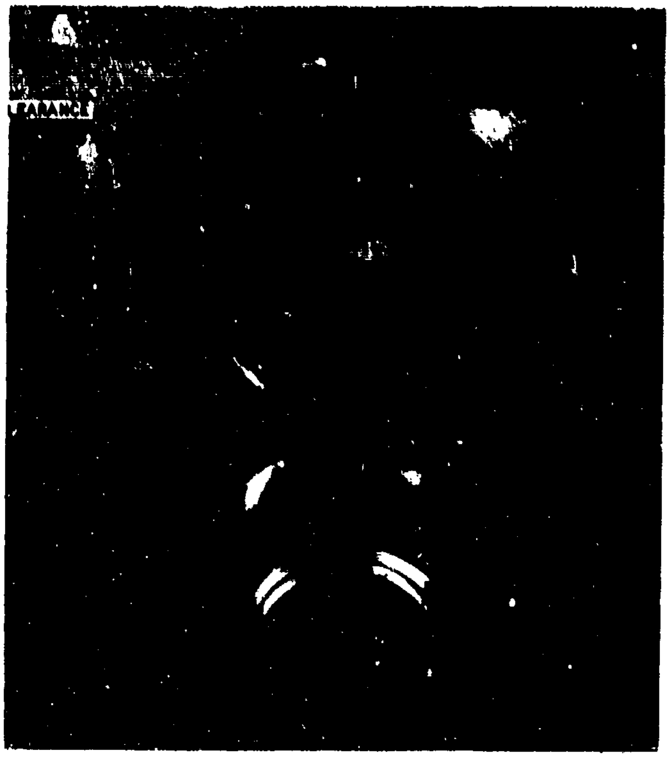


Figure 48. Clearance Between Decision and Non-Decision Knives

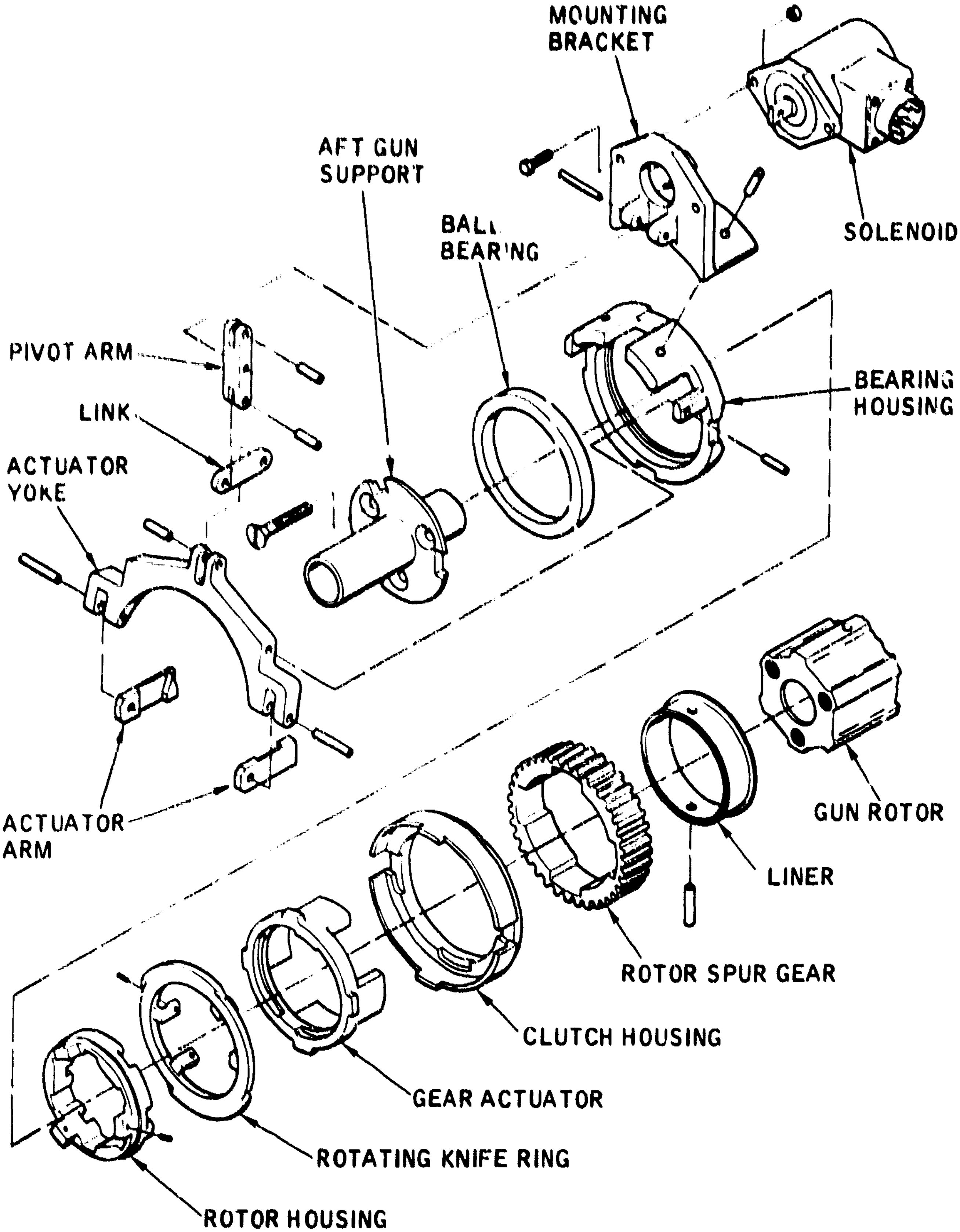


Figure 49. Exploded Clutch Assembly

APPENDIX II-C

Test Results

Table III. Live Testing Clutch Unit 1 - Module System 4/7/69

Burst No.	Fired	Gun Status	Remarks
		Loaded 500	rounds
1	34	Clear	Erratic fire - aft support screws not tight
2	81	Clear	OK
3	93	Clear	OK
4	105	Clear	OK
5	88	Hot	Failure to cam by both knives - timing finger on solenoid bracket jumped time and rotated 1/2 rev. - replaced pins in bracket, inspected parts, no damage
6	0	No go	Feed system retarded too much at stop
7	91	Clear	OK
8	91	Clear	OK
9	0	No go	Feed system retarded too much at stop
	Parts reworked		
	1. Filed steeper angle on non-decision knife so 0.050 in. clearance between non-decision knife and stationary knife when decision knife lines up edge-to-edge with stationary knife		
	2. Added 0.030 in. to rear side of stopping lug cavity in two places		
	TESTING RESUMED 4/8/69		
10	90	Clear	OK
11	96	Clear	OK
12	111	Clear	OK
13	19		OK fire out
		Loaded 1000	rounds
14	104	Clear	OK

Table III. Live Testing Clutch Unit 1 - Module System (cont.)

Burst No.	Fired	Gun Status	Remarks
15	78	Clear	OK
16	100	Clear	OK
17	97	Clear	OK
18	111	Clear	OK
19	92	Clear	OK
20	112	Clear	OK
21	.0	No go	Feed system retarded too much at stop - parts inspected - no damage - must add more material to back end of stopping lug cavity
22	92	Clear	OK
23	111	Clear	OK
24	103	Fire out	OK
		Loaded 1500 rounds	
25-35		Clear	OK - 11 bursts fired all cleared
36	0	No go	No damage, no jam - suspect wiring short
37-40	1500	Clear	OK - four bursts fired out on burst 40
		Loaded 1500 rounds	
41	0	No go	Feed system retarded too much at stop
42-50		Clear	OK
51	0	No go	No damage, no jam - suspect wiring short
52	95	Hot	High extract - gun cleared by hand - very high extract on one barrel
53-56		Clear	OK
57	1500	Fire out	OK
		Loaded 2000 rounds	
58		Clear	OK

Table III. Live Testing Clutch Unit 1 - Module System (cont.)

Burst No.	Fired	Gun Status	Remarks
59	0	No go	Feed system retarded too much at stop
60	9	Hot	Feed system mistimed - retimed
61-68		Clear	OK
69	0	No go	Feed system retarded too much at stop
70-79		Clear	OK
80	2000	Fire out	OK
81-83		Clear	OK
84	0	No go	Feed system retarded too much at stop
85	0	No go	Feed system retarded too much at stop
86		Clear	OK
87	0	No go	Feed system retarded too much at stop - added approx. 0.060 in. to end of stop lug cavity
88-93		Clear	OK
94	2000	Fire out	OK
	Rework		
	1. Added 0.030 in. to end of actuator arms		
		Loaded 2000 rounds	
95-97		Clear	OK
98		Hot	Stoppage during firing - no apparent damage - no jams
99		Hot	Round (pierced in module exit shaft) feed into gun left projectile in barrel - stoppage when next round fed into plugged barrel - primer was blown on first round but propellent not fired
100-116		Clear	OK
117	2000	Fire out	OK

Table III. Live Testing Clutch Unit 1 - Module System (cont.)

Burst No.	Fired	Gun Status	Remarks
		Loaded 2000 rounds	
118-141		Clear	OK
142	2000	Fire out	OK
		Loaded 200 rounds	
143-144		Clear	OK
145		Clear	Intermittent solenoid failure - replaced solenoid and connector
146-149		Clear	OK - battery very low - replaced battery - this probably caused failure on burst 145
150-164		Clear	OK
165	2000	Fire out	OK
		Loaded 1800 rounds	
166-179		Clear	OK
180	1800	Fire out	OK
		Loaded 2000 rounds	
181-196		Clear	OK
197	2000	Fire out	OK
		Loaded 2000 rounds	
198-206		Clear	OK
207	2000	Fire out	OK
		Loaded 2000 rounds	
208-224		Clear	OK
225	2000	Fire out	OK
		Loaded 2000 rounds	
226-239		Clear	OK
240	2000	Fire out	OK

Table III. Live Testing Clutch Unit 1 - Module System (cont.)

Burst No.	Fired	Gun Status	Remarks
		Loaded 2000 rounds	
241-260		Clear	OK
261	2000	Fire out	OK
262-265		Clear	OK
266			Jam in drum handoff - Module System shut-down as per original test plan - converted to Pod System (this system has damaged rounds on scoop disc in prior testing)
		Loaded 1500 rounds	
267-274		Clear	OK
275		Hot	Bent round in conveyor wheel
276-282		Clear	OK
283		Hot	Bent round in conveyor wheel
284	1500	Fire out	OK - changed to delinking feeder due to defective scoop disc on Pod System
		Loaded 2000 rounds	
285-292		Clear	OK
293		Hot	Mislinked round jammed in feeder
294-306		Clear	OK
307	2000	Fire out	OK
		Loaded 2500 rounds	
308		Clear	Belt broke (ammunition can too full)
309		Hot	Feeder jam
310-331		Clear	OK
332	2500	Fire out	OK
		Loaded 2000 rounds	
344-370		Clear	OK

Table III. Live Testing Clutch Unit 1 - Module System (cont.)

Burst No.	Fired	Gun Status	Remarks
371	1500	Fire out	OK
		Loaded 1500 rounds	
372-384		Clear	OK
385	0	No go	Pin in yoke assembly fell out (improperly installed)
386		Hot	System mistimed - retimed
387-396		Clear	OK
397	1500	Fire out	OK
		Loaded 1500 rounds	
398-415		Clear	OK
416	1500	Fire out	OK
		Loaded 1500 rounds	
417-420		Clear	OK
421		Hot	Feeder jam
422-440		Clear	OK
441	1500	Fire out	OK
		Loaded 1500 rounds	
442-463		Clear	OK
464	1500	Fire out	OK
		Loaded 2000 rounds	
465-485		Clear	OK
486	2000	Fire out	OK
		Loaded 2300 rounds	
487-511		Clear	OK
512	2300	Fire out	OK
		Loaded 1200 rounds	

Table III. Live Testing Clutch Unit 1 - Module System (cont.)

Burst No.	Fired	Gun Status	Remarks
513-526		Clear	OK
527	1200	Fire out	OK
		50,000 rounds - total rounds fired	

Table IV. Live Testing Clutch Unit 2 - A-37 System 6/9/69

Burst No.	Fired	Gun Status	Remarks
		Power loaded 1500 rounds	
1-16		Clear	OK
17	1500	Fire out	OK
		Power loaded 1500 rounds	
18-31		Clear	OK
32	1500	Fire out	OK
		Power Loaded 1500 rounds	
33-36		Clear	OK
37		Hot	Stoppage near beginning of burst - round out of control ahead of bolt head - debulleted attempting to enter chamber - no damage to gun
38-39		Clear	OK
40		Hot	Same stoppage as 37
41-42		Clear	OK
43		Hot	Same stoppage as 37
44	1500	Fire out	OK
		Power loaded 1500 rounds	
45-58		Clear	OK
59		Hot	Same stoppage as 37
	(Note: Further investigation revealed a damaged guide bar in the gun.)		
		Testing changed to delinking feeder	
		Loaded 2000 rounds	
60-75		Clear	OK

Table IV. Live Testing Clutch Unit 2 - A-37 System (cont.)

Burst No.	Fired	Gun Status	Remarks
76	0	No go	Burr on one of four slots on rotor housing caused cocking of rotating knife ring and subsequent stoppage - finger on solenoid bracket jumped time and rotated 1/2 rev. - burr removed, slight damage to knives
77-83		Clear	OK
84	2000	Fire out	OK
		Loaded 2000 rounds	
85-91		Clear	OK
92		Hot	Sol. bracket finger jumped time and rotated 1/2 rev. - pins on sol. bracket loose
93-96		Clear	OK
97		Hot	Same stoppage as 92 - replaced pins
98-107		Clear	OK
108	2000	Fire out	OK
		Loaded 2000 rounds	
109-134		Clear	OK
135	2000	Fire out	OK
		Loaded 2000 rounds	
136-157		Clear	OK
158	2000	Fire out	OK
		Loaded 2000 rounds	
159-183		Clear	OK
184	2000	Fire out	OK
		Loaded 2000 rounds	
185-206		Clear	OK
207	2000	Fire out	OK

Table IV. Live Testing Clutch Unit 2 - A-37 System (cont.)

Burst No.	Fired	Gun Status	Remarks
		Loaded 2000 rounds	
208-228		Clear	OK
229	2000	Fire out	OK
		Loaded 2000 rounds	
230-246		Clear	OK
	Clutch Test shut down due to insufficient time		

Table V. Continued Live Testing Unit 2

Prior Testing 246 Actuations 21,500 Rounds Fired

Burst No.	Fired	Gun Status	Remarks
	Loaded 2000 rounds		Side stripping feeder
1-21	2000	Clear	OK
	Loaded 2000 rounds		
22-32	2000	Clear	OK
	Loaded 2000 rounds		
33-42	2000	Clear	OK
	Loaded 1200 rounds		
43-50		Clear	OK
51	-	Hot	Solenoid plunger stuck
52-53	1200	Clear	OK
	Loaded 2000 rounds		
54-68	2000	Clear	OK
	Loaded 2000 rounds		
69-83	2000	Clear	OK
	Loaded 1500 rounds		
84-95	1500	Clear	OK
	Loaded 1500 rounds		
99		Hot	Solenoid plunger stuck - linkage was binding (unsymmetrical) - reversed linkage and binding was eliminated
100	-	Hot	Late feed - mistimed
101-106	1500	Clear	OK
	Loaded 1500 rounds		

Table V. Continued Live Testing Unit 2

Prior Testing 246 Actuations - 21,500 Rounds Fired (cont.)

Burst No.	Fired	Gun Status	Remarks
107	-	Hot	Right yoke pivot pin fell out causing loss of knife control - set 1/16 bearing pins - filed down resulting burrs on knife blades
108-121	1500	Clear	OK
	Loaded 1500 rounds		
122-138	1500	Clear	OK
	Loaded 1500 rounds		
139-154	1500	Clear	OK
	Loaded 1500 rounds		
155-164	1500	Clear	OK
	Loaded 1500 rounds		
165-172	1500	Clear	OK
	Loaded 1500 rounds		
173-186	1500	Clear	OK
			Clutch disassembled, inspected, and relubricated
	Loaded 1500 rounds		
187-201	1500	Clear	OK
	Loaded 1500 rounds		
202-217	1500	Clear	OK
	Loaded 1500 rounds		
218-237	1500	Clear	OK
	Loaded 1500 rounds		
238-246	1500	Clear	OK
	Loaded 1500 rounds		

Table V. Continued Live Testing Unit 2

Prior Testing 246 Actuations - 21,500 Rounds Fired (cont.)

Burst No.	Fired	Gun Status	Remarks
247-256	1500	Clear	OK
	Loaded 1500 rounds		
257-266	1500	Clear	OK
	Loaded 1500 rounds		
267-276	1500	Clear	OK
	Loaded 1500 rounds		
277-291	1500	Clear	OK
	Loaded 400 rounds		
292-295	400	Clear	OK
			Clutch disassembled, inspected, and lubricated
	Loaded 1500 rounds		
296-308	1500	Clear	OK
	Loaded 1500 rounds		
309-325	1500	Clear	OK
	Loaded 1500 rounds		
326-341	1500	Clear	OK
	Loaded 1500 rounds		
342-347	-	Clear	OK
348	-	Hot	Clutch jam - knife blades cammed both directions - solenoid bracket screws bent slightly (replaced) - no other damage
349-356	1500	Clear	OK
	Loaded 1500 rounds		
357-372	1500	Clear	OK

Table V. Continued Live Testing Unit 2

Prior Testing 246 Actuations - 21,500 Rounds Fired (cont.)

Burst No.	Fired	Gun Status	Remarks
	Loaded 1500 rounds		
373-389	1500	Clear	OK
	Loaded 1500 rounds		
390-404	1500	Clear	Clutch jam at fire out - knife blades clearance 0.048 in. increased to 0.078 in. per design change
	Loaded 1500 rounds		
405-419	1500	Clear	OK
	Loaded 1500 rounds		
420-432	-	Clear	OK
433	1500	Clear	Clutch jam - solenoid bracket screws worked loose permitting finger to jump time
	Loaded 1500 rounds		
434-446	1500	Clear	OK
	Loaded 1500 rounds		
447-452	1500	Clear	OK
	Loaded 1000 rounds		
453-463	1000	Clear	OK
	Loaded 1500 rounds		
464-476	1500	Clear	OK
	Loaded 1500 rounds		
477-491	1500	Clear	OK
	Loaded 1500 rounds		
492-506	1500	Clear	OK

Table V. Continued Live Testing Unit 2

Prior Testing 246 Actuations - 21,500 Rounds Fired (cont.)

Burst No.	Fired	Gun Status	Remarks
	Loaded 1500 rounds		
507-520	1500	Clear	OK
	Loaded 1500 rounds		
521-531	1500	Clear	OK
	Loaded 2000 rounds		
532-544	2000	Clear	OK
	Loaded 2000 rounds		
545-557	2000	Clear	OK
	Loaded 2000 rounds		
558-567	2000	Clear	OK
	Loaded 1000 rounds		
568-572	1000	Clear	OK
	Loaded 1000 rounds		
573-577	1000	Clear	OK
	Loaded 1000 rounds		
578-583	1000	Clear	OK
	Loaded 1000 rounds		
584-588	1000	Clear	OK
	Loaded 1500 rounds		
589-596	1500	Clear	OK
	Loaded 1500 rounds		
597-608	1500	Clear	OK
	Loaded 1500 rounds		
609-623	1500	Clear	OK

Table V. Continued Live Testing Unit 2

Prior Testing 246 Actuations - 21,500 Rounds Fired (cont.)

Burst No.	Fired	Gun Status	Remarks
	Loaded 1500 rounds		
624-638+	1500	Clear	OK
+ 246 prior actuations			
Total Rounds Fired = 100,000			
Total Actuations = 884			

A P P E N D I X II-D

Weight and Center of Gravity

Clutch Unit

Total Weight = 3.4805 pounds

Center of Gravity = 1.5429 inch aft of the forward edge of the bearing liner (see figure 50).

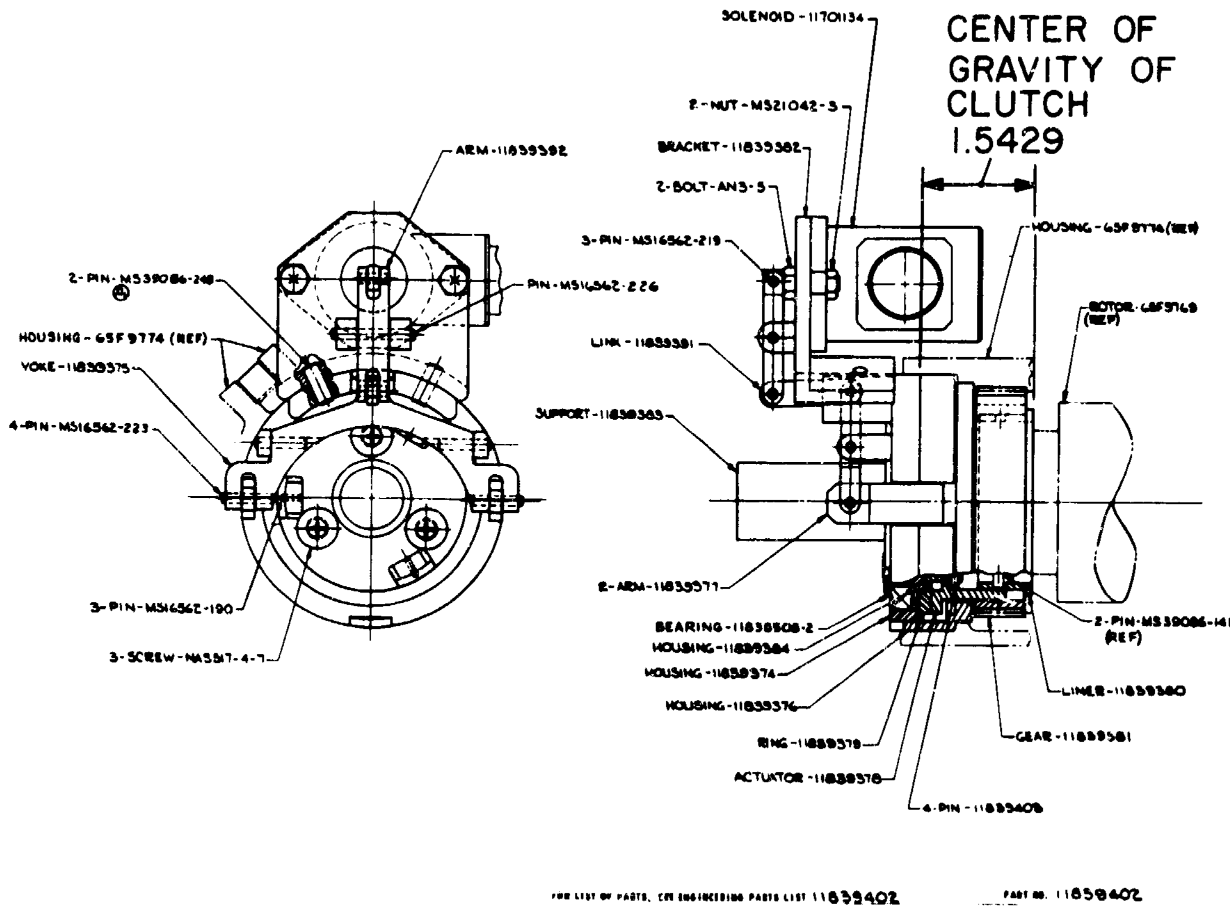


Figure 50. Clutch Assembly

A P P E N D I X II-E

Final Report Minigun Declutching System Analysis

A. ABSTRACT

The declutching mechanism has been designed and is being tested at the present time. Early test results showed some minor adjustments were needed; recent tests on the Module System have been conducted with excellent results.

The dynamic characteristics of present minigun systems and the dynamic characteristics of two forecast systems are included in this report. A stress analysis of some critical system parts has been performed and is also included.

B. INTRODUCTION

The desired declutching mechanism for the minigun is one that would be contained within the gun itself and hence be available to all of the several feed systems.

The mechanism generally considered would disconnect the rear drive gear from the rotor and stop the feed system at particular locations of the feeder sprocket so there would be no interference due to the round's being between the feeder and the gun during the handoff operation of the feeder. The advantages of this mechanism are in the saving of ammunition and in stopping the gun, normally with no ammunition in the gun, in the safe stopped condition. The two main difficulties in incorporating this mechanism in the gun are - the space limitations within the gun and the probably high inertial loads on the several parts of the feed systems after a sudden stoppage.

C. APPROACH

A two-part program was undertaken to gain knowledge of the dynamics and loads of the present systems and to forecast the dynamics and loads of future systems. The first was an experimental test program conducted to show the torque-time-acceleration characteristics of the systems. The second part was an analytical solution using the digital and analog computers to find solutions that correlate with present systems and solutions for systems with new design requirements.

D. TEST PROGRAM

A test device was designed to disconnect the rear gear from the gun rotor at a particular location, where the rounds are fully contained in either the feed system or the gun, and to stop the feed system almost immediately after the disconnect. The stop device was instrumented to give a trace of torque versus time during the very short time during which the inertial loads build up. Several curves of peak torque versus rate, presented on the following pages, show the maximum torque which may be expected for the several systems.

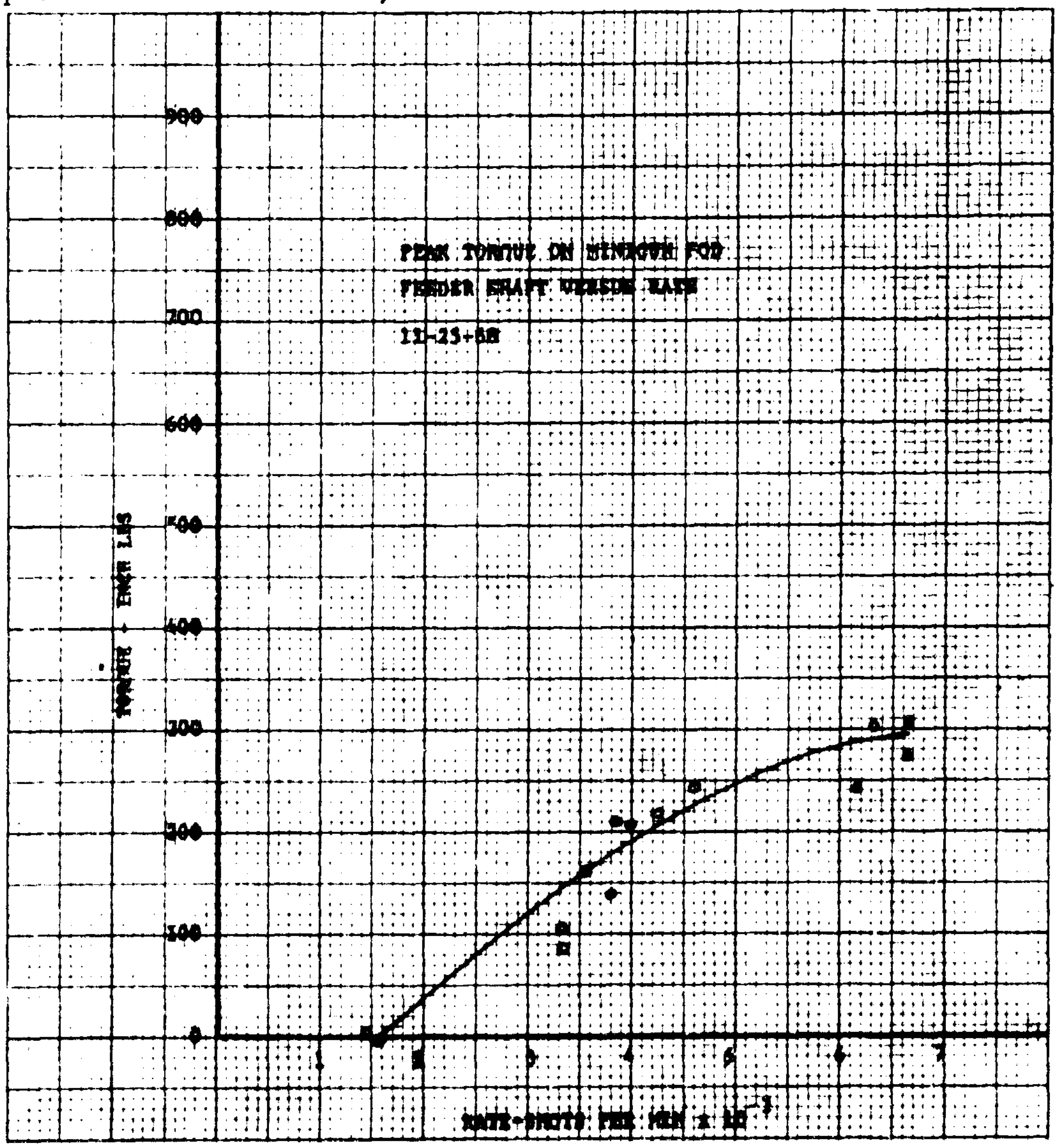


Figure 51. Peak Torque on Minigun Pod Feeder Shaft vs Rate

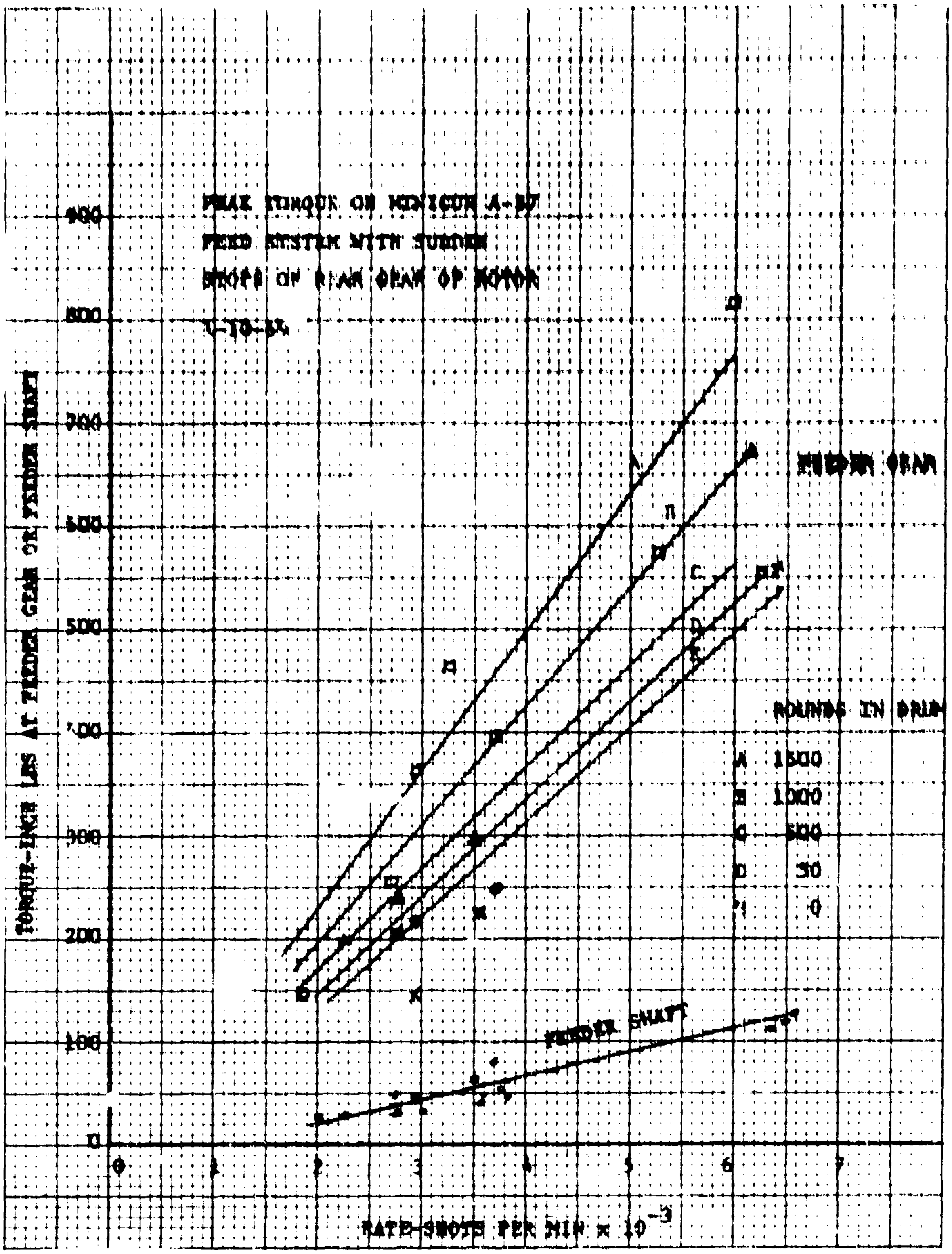


Figure 52. Peak Torque on Minigun A-37 Feed System with Sudden Stops of Rear Gear of Rotor

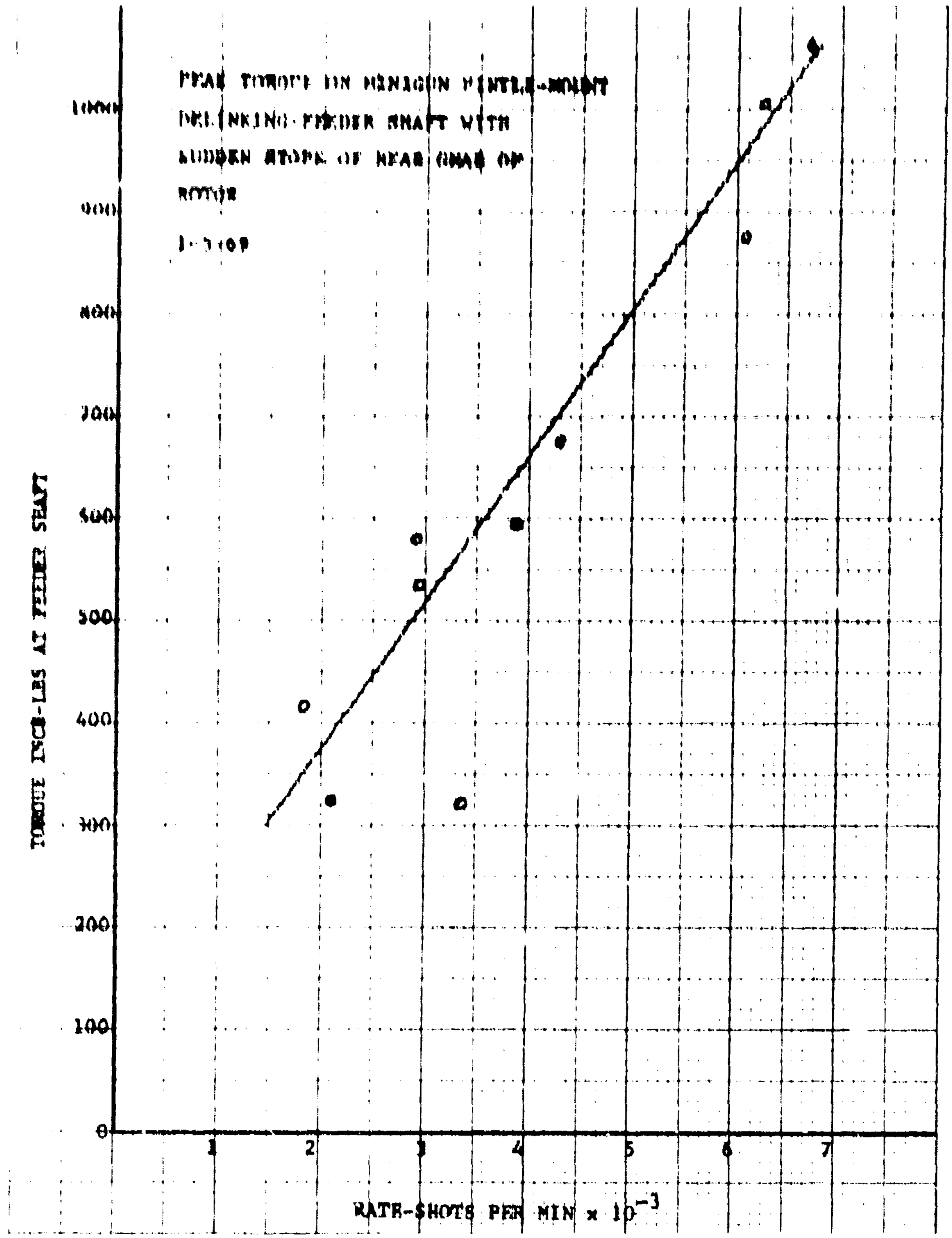


Figure 53. Peak Torque on Minigun Pintle Mount Delinking Feeder Shaft with Sudden Stops of Rear Gear of Rotor

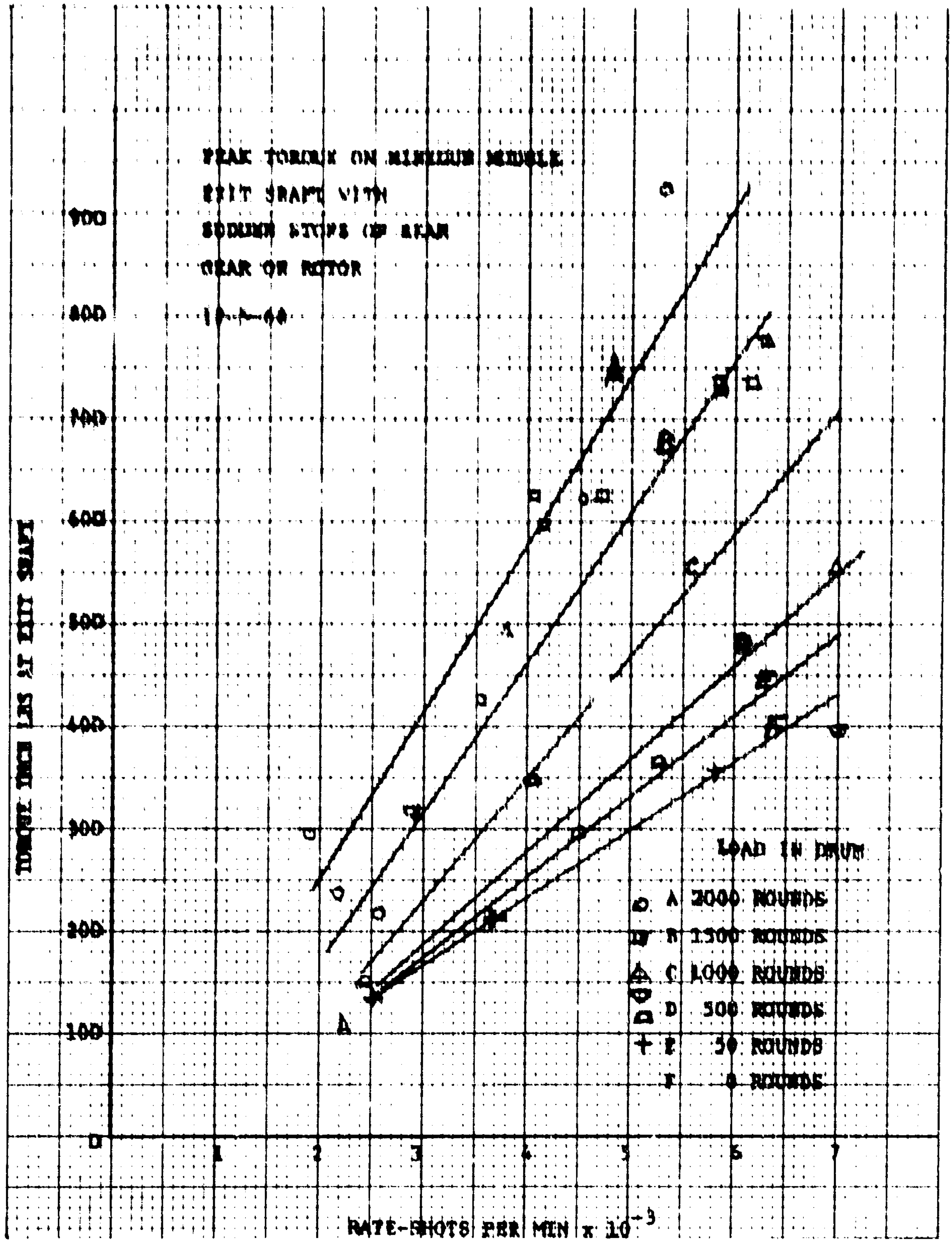


Figure 54. Peak Torque on Minigun Module Exit Shaft with Sudden Stops of Rear Gear on Rotor

E. PEAK LOADS IN THE SEVERAL MINIGUN SYSTEMS WITH SUDDEN STOPS

The peak torques on the several minigun systems are presented in the preceding graphs and are tabulated below for sudden stops from 6000 spm with full drums (where applicable). The most highly stressed part is indicated, and the peak load is compared to the allowable load.

The peak loads expected on the most highly stressed parts are less than the allowable loads except for the new 3000-round Pod System with a new feeder and a module-type drum. This system develops a 4900-pound load on a pin that has a maximum allowable strength of 3000 pounds. This particular pin is a C-type pin; a roll pin could be substituted to increase the allowable load to 4400 pounds. However, if this system were slowed to 3000 spm before a sudden stop the peak load of 2740 pounds is less than the allowable load of 3000 pounds.

Table VI. Peak Torques for Sudden Stops from 6000 spm

SYSTEM	PEAK TORQUE (INCH-POUNDS)	LOCATION OF PIN	PIN MS NO.	SHAFT DIA. (INCHES)	PEAK LOAD (POUNDS)	ALLOWABLE LOAD POUNDS
Present Pod	280	Fdr. Drive Gear	16562-231	0.375	1490	3000
AT-37	760	Fdr. Drive Gear	39086-250	0.500	3040	4400
Module	900	Exit Shaft Drive Gear	39086-250	0.500	3600	4400
Delinking Feeder (MAU-58)	950	Feeder Sprocket	39086-251	0.624	3050	4400
3000-Rd. Pod & New Fdr. & Mod.-Type Drum	1224	Fdr. Drive Gear	16562-232	0.500	4900	3000
3000-Rd. Pod & New Fdr. & Mod.-Type Drum at 3000 spm	685	Fdr. Drive Gear	16562-232	0.500	2740	3000

F. ANALYTICAL INVESTIGATION

Fundamental information regarding the dynamics involved with engagement of the several minigun systems is desired. When engagement occurs at the gun, the feed system's inertia will develop loads depending upon the inertia, spring constants, and friction involved. The most simple differential equation that might give reasonable answers to the above is the classic spring-mass system equation with friction force porportional to velocity. A second differential equation that is more realistic for cases where ammunition is rotated and slides in a drum, as in the Module System, is the differential equation for a spring-mass system, but with a friction force which varies as the second power of the velocity. Both systems are investigated here, and they agree to a large extent since friction does not occur over a sufficiently long time to cause large differences.

G. SUMMARY OF RESULTS OF THE ANALYTICAL INVESTIGATION

The present Module System, with 2000 rounds in the drum and a rate of 6000 spm develops 500 foot-pounds of torque at the drum clutch engagement. The same type of system with 3000 rounds in the drum will develop 600 foot-pounds of torque at the drum.

A new Pod System with 3000 rounds in a module-type drum will develop 680 foot-pounds of torque at the drum at 6000 spm; if actuated at 3000 spm, it will develop 380 foot-pounds of torque. The above results were obtained with a measured spring constant of 3380 foot- pounds per radian at the drum for the present Module System and with a spring constant of 4430 foot-pounds per radian at the drum for the new Pod System. The new pod spring constant was measured with the new heavier feeder shaft.

II. DISCUSSION

The digital computer was programmed for the equation:

$$I \frac{d^2\phi}{dt^2} + I\,2b \frac{d\phi}{dt} + K\phi = 0$$

and the analog computer was programmed for the equation:

$$I \frac{d^2\phi}{dt^2} + 2BI \left(\frac{d\phi}{dt}\right)^2 + K\phi = 0$$

If the first terms are thought of as total torque, the second terms as friction torque, and the third terms as spring torque - and deceleration begins from the same initial conditions - it is obvious that during the stop the friction torque for the second equation (analog) will decrease more rapidly with time than the friction torque for the first equation (digital). Consequently the peak spring torques for the analog model will be generally higher than those of the digital model, but the differences are not large (less than five percent) and the two methods tend to verify each other. One interesting observation was that neither model damped as quickly as the experimental. The high-speed movies gave a possible explanation for this. The camera angle was such to observe that during the stop, while the motion of the inner drum generally follows a damped sine curve pattern, higher frequency oscillations occurred - the inner drum fins very likely oscillated the rounds from one fin to the next and back many times during the stop. This would dissipate the stored kinetic energy much faster than either of the two mathematical models and would account for the rapid experimental damping observed.

The several present minigun systems should be capable of withstanding the sudden stopping loads owing to the declutching mechanism. The AT-37 system will need an additional bearing to insure continuous contact of the drum ring gear and its mating pinion, but this modification is a minor one.

1. MATHEMATICAL FORMULATION (FOR DIGITAL COMPUTER)

The simple spring mass system with friction force, which varies linearly with velocity, may be written in terms of rotational inertia as follows:

$$\frac{d^2\phi}{dt^2} + 2b\frac{d\phi}{dt} + \frac{K}{I}\phi = 0$$

where

$$\phi = Ce^{-bt}\sin(\alpha t + a)$$

$$\frac{d\phi}{dt} = C\alpha e^{-bt}\cos(\alpha t + a) - Cbe^{-bt}\sin(\alpha t + a)$$

$$\frac{d^2\phi}{dt^2} = C(b^2 - \alpha^2)e^{-bt}\sin(\alpha t + a) - 2C\alpha be^{-bt}\cos(\alpha t + a)$$

It will be found upon substitution of the last three equations into the first that a necessary requirement is that $\frac{K}{I} = \alpha^2 + b^2$.

The above four equations form the basis for writing the computer program included herein for the digital computer and produce the results indicated in the abstract. Briefly, the moment of inertia of the empty Module System was determined from acceleration tests with strain gauges which found torque at the exit shaft and acceleration read from recording galvanometer tapes. The moment of inertia of a round in the drum is calculated here, and the total moment of inertia is thereby available. The spring constants of the Module System and the Pod System were found by torque-deflection tests as specified herein.

In order to find the torque buildup of the feed system alone, a solenoid actuated device was built which would disconnect the rear rotor gear from the rotor while running, and then stop the feed system by inserting a solid obstruction at the rear gear. This was done with the several feed systems, and exit shaft torque, speed, and high-speed motion pictures were taken as the systems were stopped. This latter data along with the steady state friction torque allowed a correlation of the system behavior with the mathematical model. In effect, various values of the damping constant b were inserted into the computer program until a good match of initial friction torque and peak spring torque was obtained using the Module System as the experimental system.

In order to predict the behavior of a new Pod System which would use a module-type drum, the damping constant b was assumed to vary directly as the drum load.

J. DIGITAL COMPUTER PROGRAM

In the following Fortran four digital computer program, the rate, spring constant, rounds in drum, and frictional constant b are read. The inertia is calculated as shown in Appendix II-F. Since $\alpha = 2\pi/TP$ where TP is the period, the equation $K/I = \alpha^2 + b^2$ gives TP. The initial speed of the drum in radians/sec $\frac{d\phi}{d\theta}\Big|_{t=0}$ is calculated from spm and the gear ratio. The constant C is obtained from $C = (\frac{d\phi}{dt}\Big|_{t=0})(TP)/2\pi$. ϕ = FE is found from the second equation of the formulation and converted to degrees FEDGR. $d\phi/dt$ = DFEDT is found likewise, from equation 3. And $d^2\phi/dt^2$ = DTODT is from equation 4. The term total torque TOTQ in inch-pounds is from (I) $(\frac{d\varphi}{dt})$ (12). The program listing gives time, degrees of deflection of the drum, velocity, total torque, friction torque, spring torque, DELTQ a difference between the total torque, and the sum of spring and friction torque and acceleration. Also listed is α, spm, spring constant, rounds in drum, period, inertia, the constant C, the friction constant Beta, and a check on the inertia COPIA.

```
// JOB T
// FOR
*ONE WORD INTEGERS
*EXTENDED PRECISION
*IOCS(CARD,1132 PRINTER)
*LIST ALL
C      ME-243,PROBLEM 4-28
  500 READ(2,1000)SPM,SPCON,RONDS,BETA
 1000 FORMAT(4F10.4)
 1030 FORMAT(1H1,48X,'TANK BLOWDOWN PROBLEM',//,4X,'TIME',7X,'DEGREES',
     16X,'VELOCITY',7X,'TOTORQUE',5X,'FRITQUE',5X,'SPRITQUE',6X,'DELTQ',
     26X,
     3'ACCL',//, 4X,'SEC',10X,'O',10X,'RAD/SEC',8X,'INXLBS',7X,'INXLBS',
     46X,'INXLBS',7X,'INXLBS',3X,'RAD/SECXSEC',//)
 1040 FORMAT(8E13.5)
 1050 FORMAT(1H1,5X,'ALPHA',9X,'SPM',8X,'SPCON',8X,'RONDS',5
     1X,'PERIOD',7X,'ERTIA',9X,'CO',9X,'BETA',8X,'COPIA',2X)
 1060 FORMAT(10F12.5)
       WRITE(3,1030)
       T=0.0
       PI=3.14159
       EP1=2.71828
      ERTIA=(166.+RONDS*.8714)/4640.
      TP=2.*PI/((SPCON/ERTIA)-BETA**2.)**.5
       DFEDO=SPM/383.
       SEE=DFEDO*TP/(2.*PI)
       ALPHA=2.*PI/TP
   20 DO 50 I=1,40
      FE=SEE*SIN(ALPHA*T)/EP1**(BETA*T)
      FEDGR=FE*57.3
      DFEDT=((SEE*2.*PI/TP)/EP1**(BETA*T))*COS(2.*PI*T/TP)-(SEE*BETA/
     1(EP1**(BETA*T)))*SIN(2.*PI*T/TP)
      DTODT=(SEE*(BETA**2.-ALPHA**2.)*SIN(ALPHA*T))/EP1**(BETA*T)-
     1(2.*SEE*ALPHA*BETA*COS(ALPHA*T))/EP1**(BETA*T)
      TOTQ=ERTIA*DTODT*12.
       FRITQ=2.*BETA*DFEDT*ERTIA*12.
      SPTQ=SPCON*FE*12.
      DELTQ=TOTQ+FRITQ
      WRITE(3,1040)T,FEDGR,DFEDT,TOTQ,FRITQ,SPTQ,DELTQ,DTODT
   50 T=T+.002
      COPIA=SPCON/(ALPHA**2.+BETA**2.)
      WRITE(3,1050)
      WRITE(3,1060)ALPHA,SPM,SPCON,RONDS,TP,ERTIA,SEE,BETA,COPIA
       GO TO 500
  150 CALL EXIT
      END
```

Figure 55. Program for Feed Systems with Sudden Stops

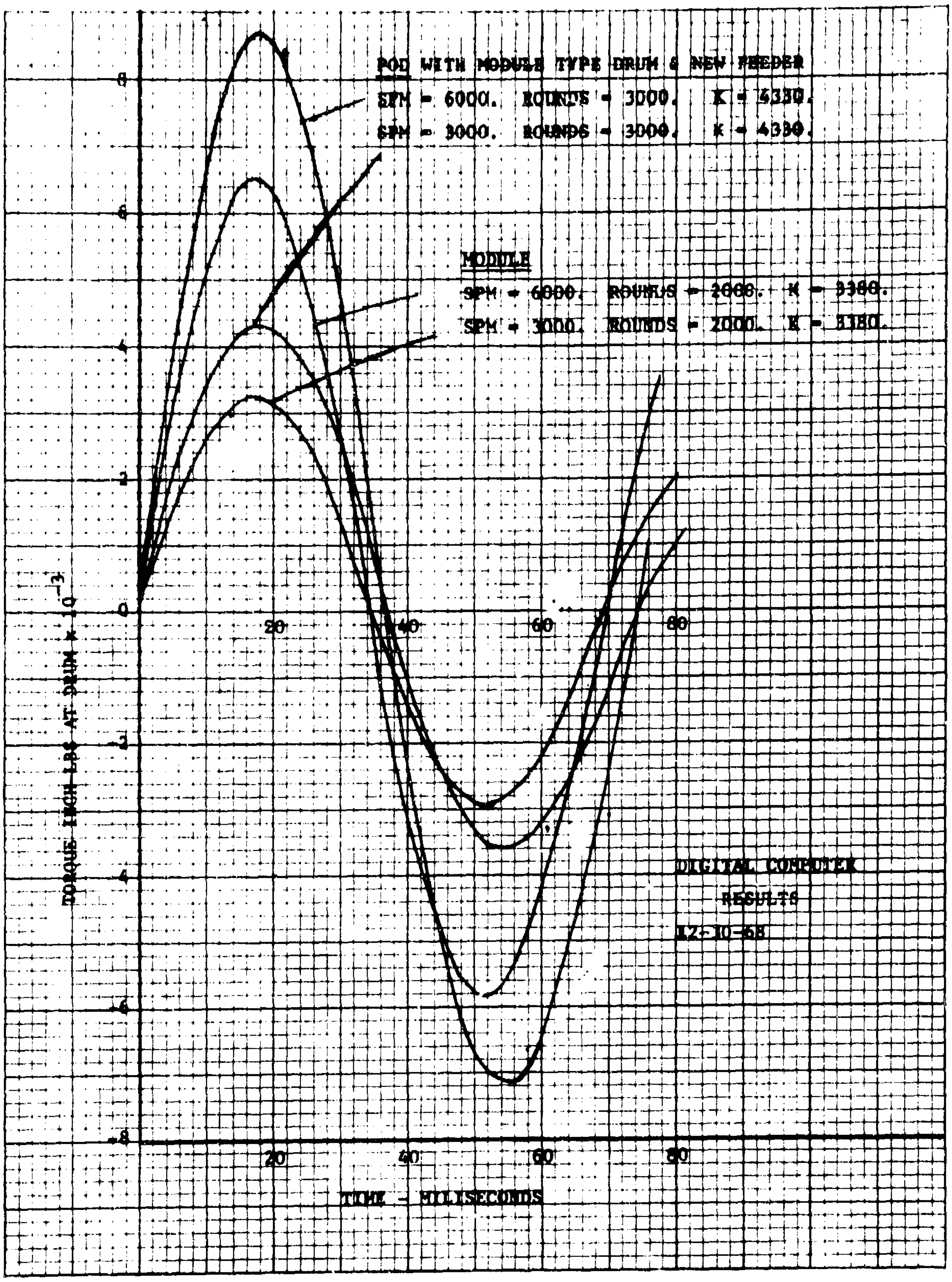


Figure 56. Pod with Module-type Drum and New Feeder

K. MATHEMATICAL FORMULATION (FOR ANALOG COMPUTER)

The spring mass system with friction force, which varies as the second power of velocity, may be written in terms of rotational inertia as follows:

$$\frac{d^2\phi}{dt^2} + 2B\left(\frac{d\phi}{dt}\right)^2 + \frac{K}{I}\phi = 0$$

or

$$I\frac{d^2\phi}{dt^2} + 2BI\left(\frac{d\phi}{dt}\right)^2 + K\phi = 0$$

In the second equation the first term may be thought of as the inertia torque, the second term as the friction torque, and the third term as the spring torque or the torque which results in torsional deflection of the system. This equation is thought to be more representative of the Module Feed System, since the ends of the rounds slide on the stationary outer drum and, if the friction coefficient is assumed to remain constant, the frictional force and consequently the frictional torque may be considered to be a function of the normal force between the rounds and the outer drum. Since the normal force is a function of orientation of the drum to the gravitational field and also of centrifugal force, the first effect is considered constant; and the friction torque term includes a velocity squared term which accounts for the second effect.

A diagram of the analog computer components is included on the next page, and the curves of spring torque at the drum versus the friction constant B are presented as a summary of the data curves found in Appendix II-F.

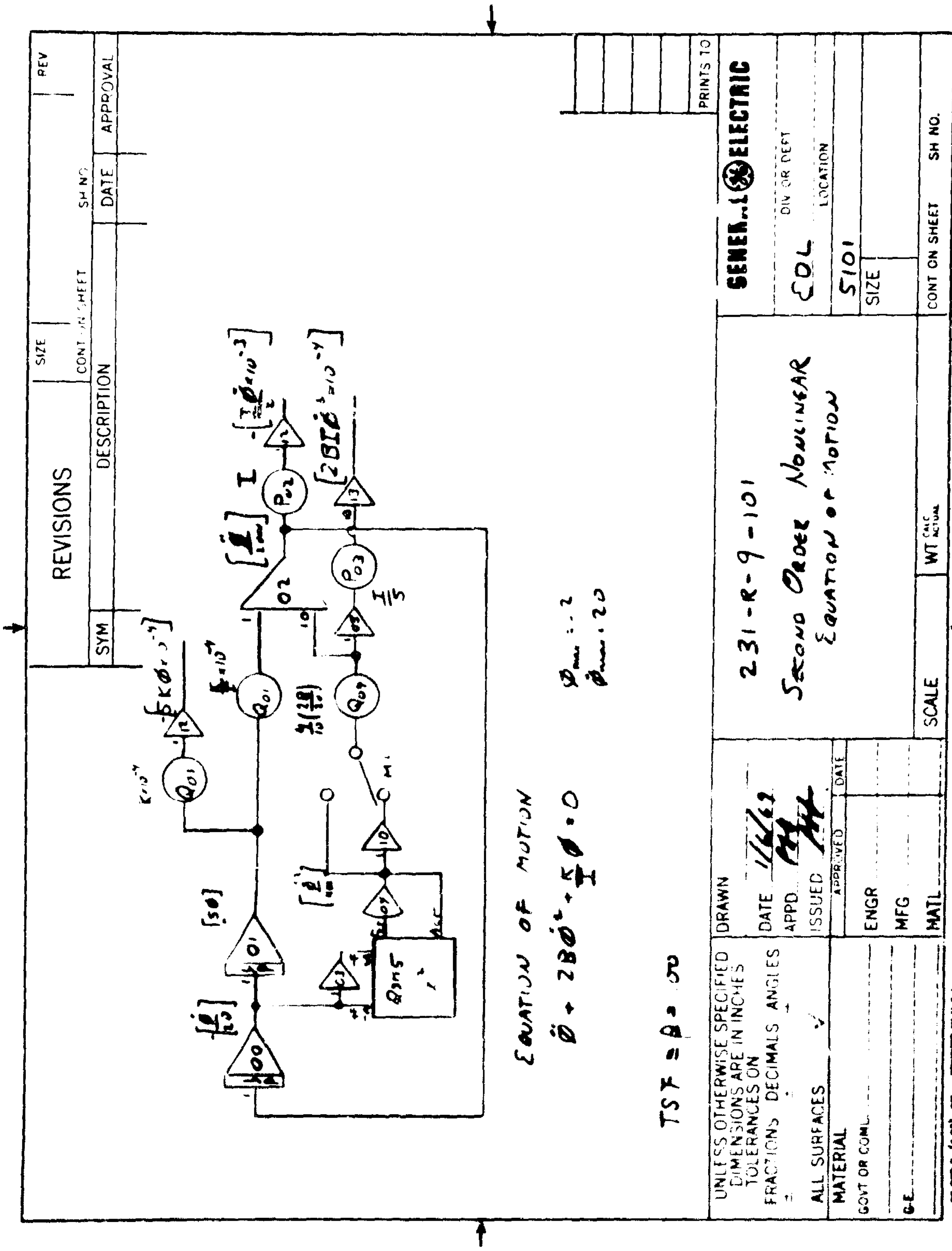


Figure 57. Second Order Nonlinear Equation of Motion

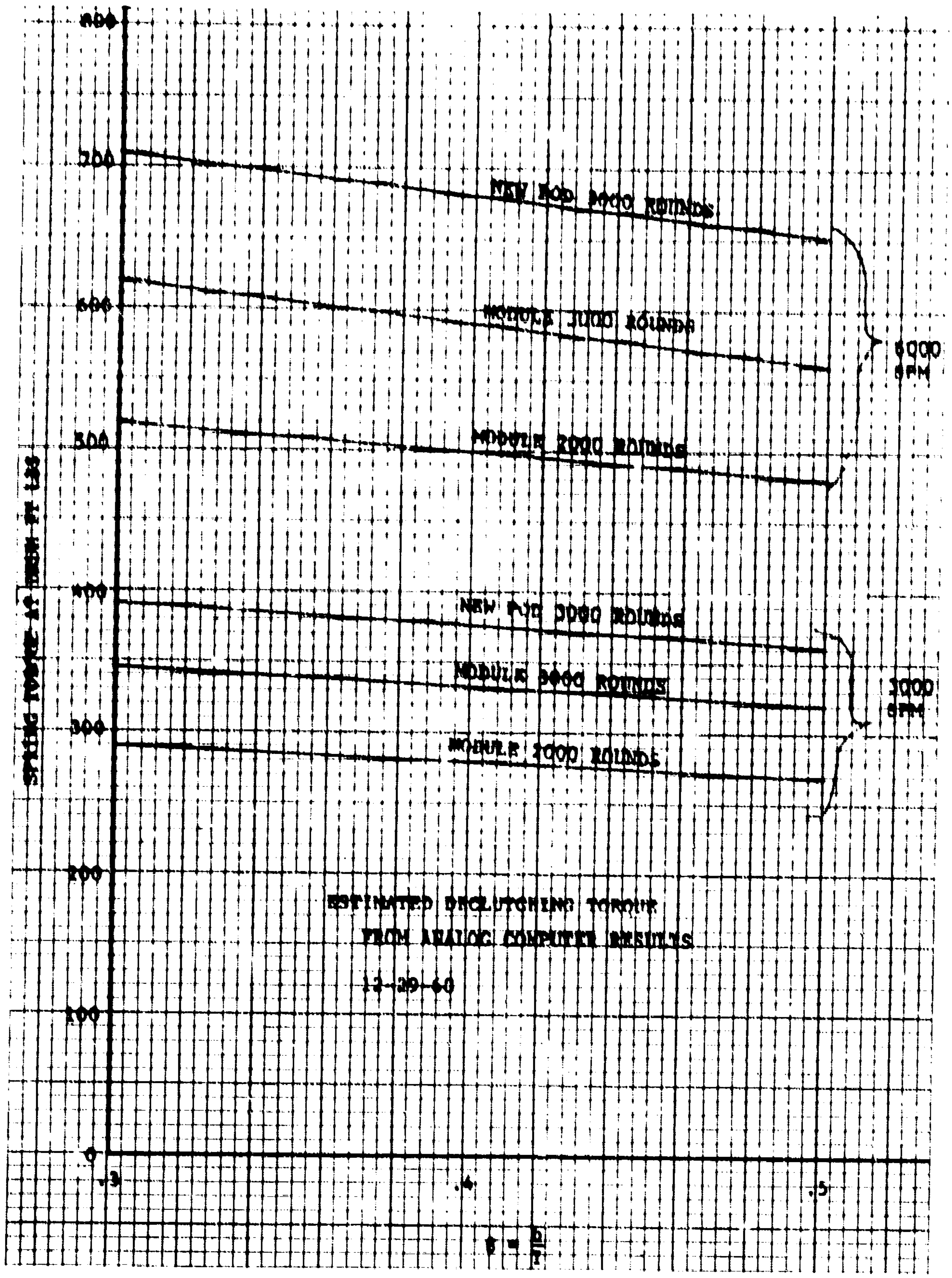


Figure 58. Declutching Torque Estimated from Analog Computer Results

L. DISCUSSION OF ANALOG COMPUTER RESULTS

The results of the analog computer program are given on the preceding graph (Figure 58) as spring torque at the drum for various values of B and for the Module or Pod System with 2000 or 3000 rounds in the drum. A range of B values was used to obtain a best fit of initial conditions of friction torque just prior to clutch actuation; the best fit information agreed well with the experimental peak torque for the 2000-round module at 6000 spm. The results at B = 0.4 best fit these initial conditions and are used to produce the results stated previously. The inertia at the 3000-round load is assumed to be 1.5 times that of the 2000-round load.

M. STRESS ANALYSIS OF THE DECLUTCHING MECHANISM

In order to obtain dynamic information quickly, the test apparatus described in the first few pages of this report was used at an early stage of this investigation to stop the several feed systems suddenly. High-speed movies and strain gauge instrumentation recorded the dynamic information presented there. It was expected that this experimentation would cause some deformation of the spring pins or roll pins, and these were examined at several stages, but no such deformation (set pins) actually occurred. The feeder gear spring pin on the Pod System was monitored very closely and a conclusion was drawn that set pins that had been reported previously with this system must have been due to a stoppage of the feed system which allowed peak drive motor torque plus inertia to be applied in order to set the pins. The several systems - Pod, Module, A-37, Pintle Mount with delinking feeder - were actuated approximately 100 times from a 6000 spm rate with no deformation of parts. The allowable load summary for the pins is given in the early pages of this appendix for the above systems and also for new design requirements.

The present feed systems appear to be capable of withstanding the loads imposed by the declutching action. However, the newly designed clutch which fits into the present minigun housing is necessarily small, and a stress analysis of some of the critical areas of this design follows.

The March 1, 1969 preliminary minigun declutching mechanism design was studied for possible high stress areas. Regions examined in detail were as follows:

1. The clutch housing restraining lugs were stress analyzed for shear failure.

2. The clutch housing lug socket was examined for a possible conical shear fracture at the end of the socket.

3. The internal lugs of the actuator gear, which engage to start the feed system, were analyzed.

4. The rear rotor gear was analyzed in the area between the root of the teeth and the section of the gear cut out to accept the actuator gear tangs.

The most highly stressed areas are at the internal lugs of the actuator gear, which engage to start the feed system. The maximum allowable torque at the actuator gear is calculated to be 5310 inch-pounds. Recent tests and calculations show the maximum torque expected on a disengagement to be 1080 inch-pounds at this location. However, a greater applied torque probably will occur on engagement to start the feed system, especially if engagement occurs when the gun is turning rapidly with the feed system stopped and the system motor on.

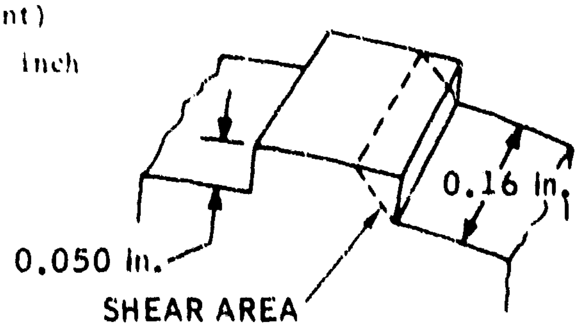
N. RECOMMENDATION

It is recommended that part 11839384, rotor housing, be altered by removing the note to chamfer 10 places 0.05+0.01. It is also recommended that part 11839378, actuator gear, be altered by slightly undercutting the ends of the inner engagement lugs as described herein to allow proper mating of the two parts. The change will increase the allowable torque at the internal lugs of the actuator gear by 87 percent. It will also decrease the shell thickness of the actuator gear from 0.100 inch to 0.091 inch in the local area of the cut, which is a less seriously stressed area.

O. <u>CLUTCH HOUSING RESTRAINING LUG TORQUE CAPABILITY</u>

3.1496-inch OD - 2.950-inch ID = 0.1996-inch or about .050 thick section (minimum engagement)

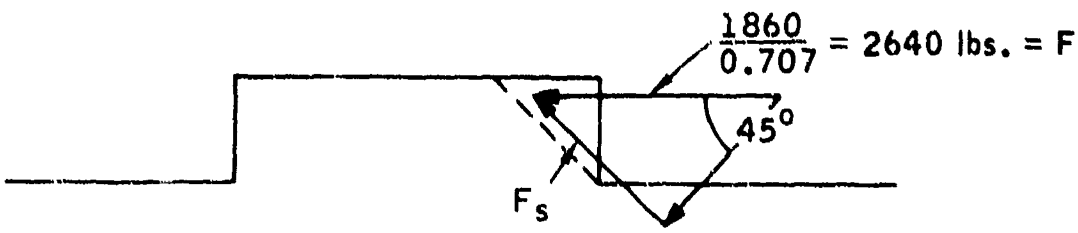
lug height = 0.16 inch



Shear Area = $\frac{(0.050)(0.16)}{0.707}$ = 0.0113 square inches

σ s allowable = (0.6)(σ ult tensile) = (0.6)(275,000) = 165,000 psi

Fs = σsA = (165,000)(0.0113) = 1860 pounds per lug



Moment capability + (F)(Dia) = (2640) (2.950+0.050) = 7600 inch-pounds

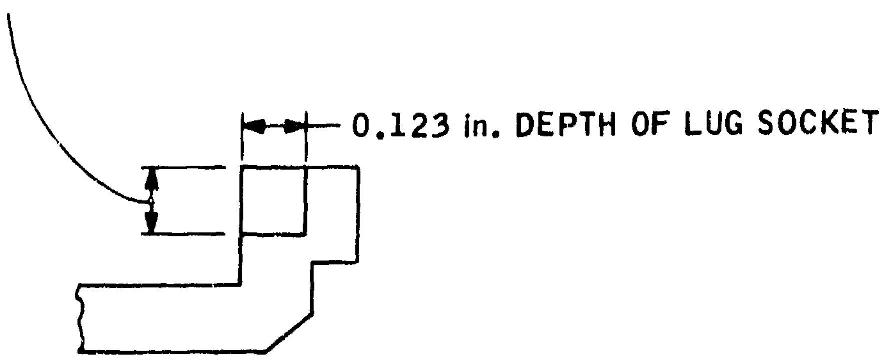
P. <u>CLUTCH LUG SOCKET LOAD CAPABILITY IN CLUTCH HOUSING</u>

O.D. Actuator Gear = 2.720

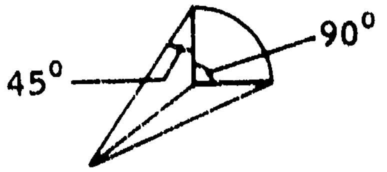
I.D. Clutch Housing = 2.450

0.270 overlap on diameters

or 0.135 overlap on radius



Assume a 90 degree conical shear fracture occurring on a 45 degree angle with the surface.



Cleavage surface area = 1/4 (cone area)

$$= 1/4\ (2\pi\ r\ \text{mean})(\text{slant height})$$

$$= \frac{\pi}{2}\ \frac{(0.0645)(0.129)}{(0.707)} = 0.0185\ \text{inches}^2$$

Load capacity in cleavage direction = (0.0185)(165,000) = 3030 pounds

Allowable load in the tangential direction $= \frac{3030}{0.707} = 4290$

Allowable torque = (Dia)(Allowable tangential load)

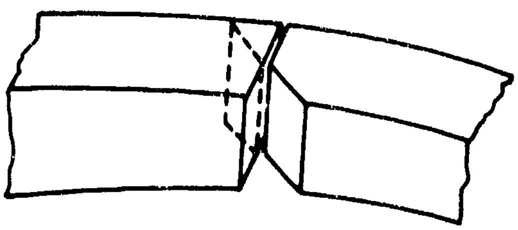
= (2.50)(4290) = 10,700 inch-pounds

Q. CLUTCH LUG LOAD CAPABILITY IN INTERNAL LUGS OF ACTUATOR GEAR

The rotor housing is chamfered back on the starting lug face 0.050 inch, which leaves only 0.057-inch face width as follows: $\frac{2.181\text{-inch} - 1.966\text{-inch}}{2}$ - 0.050 inch

$$\frac{0.215}{2} - 0.050 = \begin{matrix} 0.107 \\ 0.050 \end{matrix} = 0.057\text{-inch wide lug face}$$

The section is 0.136 inch high.



If the face shears on the mating gear actuator, the area sheared is

$$\frac{(0.057)(0.136)}{0.707} = 0.01096$$

or an allowable tangential force of $\frac{(0.01096)(165,000)}{0.707} = 2560$

Allowable torque = $(2560)\left(\frac{2.181 + 1.966}{2}\right)$

$= 5310$ inch-pounds

This is the smallest allowable torque calculated thus far, and it indicates a possible trouble spot. The allowable torque is based upon load carried by both lugs simultaneously.

R. ANALYSIS OF STRESS IN REAR GEAR ON ROTOR (REGION BELOW TEETH ROOTS)

2.576 Root diameter of gear teeth

2.400 ← Dia. of slot inside gear ring

0.176 = Thickness below root of teeth

Width of gear = 0.61 inch

Tensile area = (0.61)(0.176)

Assume tensile strength of 4140 steel = 150 KSI

Tensile load - (0.61)(0.176)(120,000) = 12,900 pounds

Allowable torque based on tensile strength $= \frac{2.5}{2}(12,900) = 16,150$ inch-pounds torque

Allowable load based on shear stress $= \frac{(0.61)(0.176)}{(0.707)^2}(75,000) = 16,100$ pounds

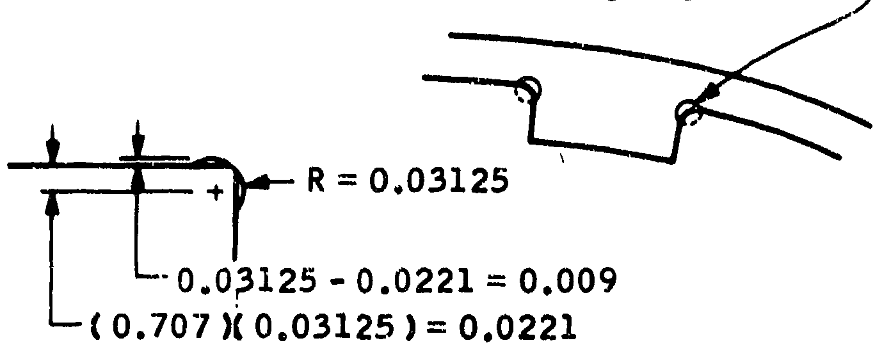
Allowable torque based on shear strength $= (16,100)(1.25) = 20,150$ inch-pounds

S. POSSIBLE MODIFICATION OF ACTUATOR GEAR DESIGN

Part 11839376

Undercut the two interior lugs so that the 0.050-inch chamfer on the housing rotor mating recess is not necessary.

Drill 1/16-inch diameter holes on either end of the lug as per sketch



If done in this manner, there is a 0.009-inch undercut. Since the shell thickness is 0.100-inch, the 0.009-inch undercut does not appear to be too great.

Table VII. Torque at Rear Gear of Rotor on Declutching of Feed System

System	Torque at Rear Gear of Rotor (inch-pounds)
Present Pod	336
AT-37	912
Module	1080
Delinking Feeder	728
New Side Strip Feeder	
at 6000 spm	1470
at 3000 spm	820

APPENDIX II-F

A. DECLUTCHING MECHANISM ANALYSIS, MOMENT OF INERTIA OF THE MODULE FEED SYSTEM

The design of a test mechanism to obtain torque versus time during sudden stoppage of the ammunition feed system was described previously. The moments of inertia of the several systems will be most important in that investigation, since in cases where the feed system is stopped rapidly, the inertial effects will generate forces which may require the redesign of certain parts. The purpose of the following analysis is to describe the method by which the moment of inertia of the Module Feed System is obtained. This information will be used to predict peak torque at other inertias, frictions, and spring constants.

The Module System was run in the Development Laboratory with no ammunition using an Air Force drive at several speeds. The feeder was instrumented with strain gauges on either side of the drive gear so that the torques for both the sprocket and for the drum drive were obtained. A speed transducer was used on the system in addition to the rounds indicator so as to have instantaneous speed recorded on the trace. The fundamental basis for the determination of the moment of inertia of the Module Feed System is the equation $Tq = I\alpha$ or torque = moment of inertia of mass times the angular acceleration of the system. The velocity and torque data are taken during the start-up acceleration period, and the moment of inertia of the drum is calculated from these data as follows:

The data are from test 20 for a module with no rounds in the drum. The controller is set for Army low rate.

$$\begin{aligned} \text{spm at 20 milliseconds} &= 810 \\ \text{spm at 10 milliseconds} &= \underline{225} \\ \text{spm} &= 585 \end{aligned}$$

$$\alpha = \frac{585 \times 2\pi}{(0.01)\ (60)\ (6)} = 1020 \text{ radians/sec}^2$$ acceleration of the gun rotor. Since there is a $6\frac{2}{3}$ to 1 ratio between the drum and the rotor

$$\alpha_{\text{drum}}\ \frac{1020}{6.66} = 153 \text{ radians/sec}^2$$

The torque at the feeder gear is the sum of the sprocket torque plus the drive gear torque and at the 15 millisecond time instant $t_{q\ F} = 8.90$ inch-pounds.

From the plot of steady state torque versus spm at 517 spm $t_{qFSS} = 0.70$ inch-pounds.

So the torque at the feeder required for acceleration is

$$t_{qFa} = t_{qF} - t_{qFSS}$$

$$t_{qFa} = 8.90 - 0.70$$

$$= 8.20 \text{ inch-pounds}$$

The Module System has a five-tooth feeder sprocket so the ω gun $= \frac{5}{6}\,\omega$ feeder and since $(t_q\ \omega)_{\text{feeder}} = (t_q\ \omega)\text{gun}$,

also

$$tq_{drum}\ \omega_{drum} = tq_{gun}\ \omega_{gun}$$

$$tq_{drum} = (8.2)\ (\frac{6}{5})\ \ (\frac{40}{6}) = 65.5$$

$$I = Tq/\alpha$$

$$I_{drum} = (\frac{65.5}{12})\ (144)\ (32.2)\ (\frac{1}{153})$$

$$I = 166.\ in^2\ lb_m$$

Data from three other tests verified the I = 166 for the moment of inertia of the Module Feed System (drum to feeder) when considered lumped at the drum (when empty).

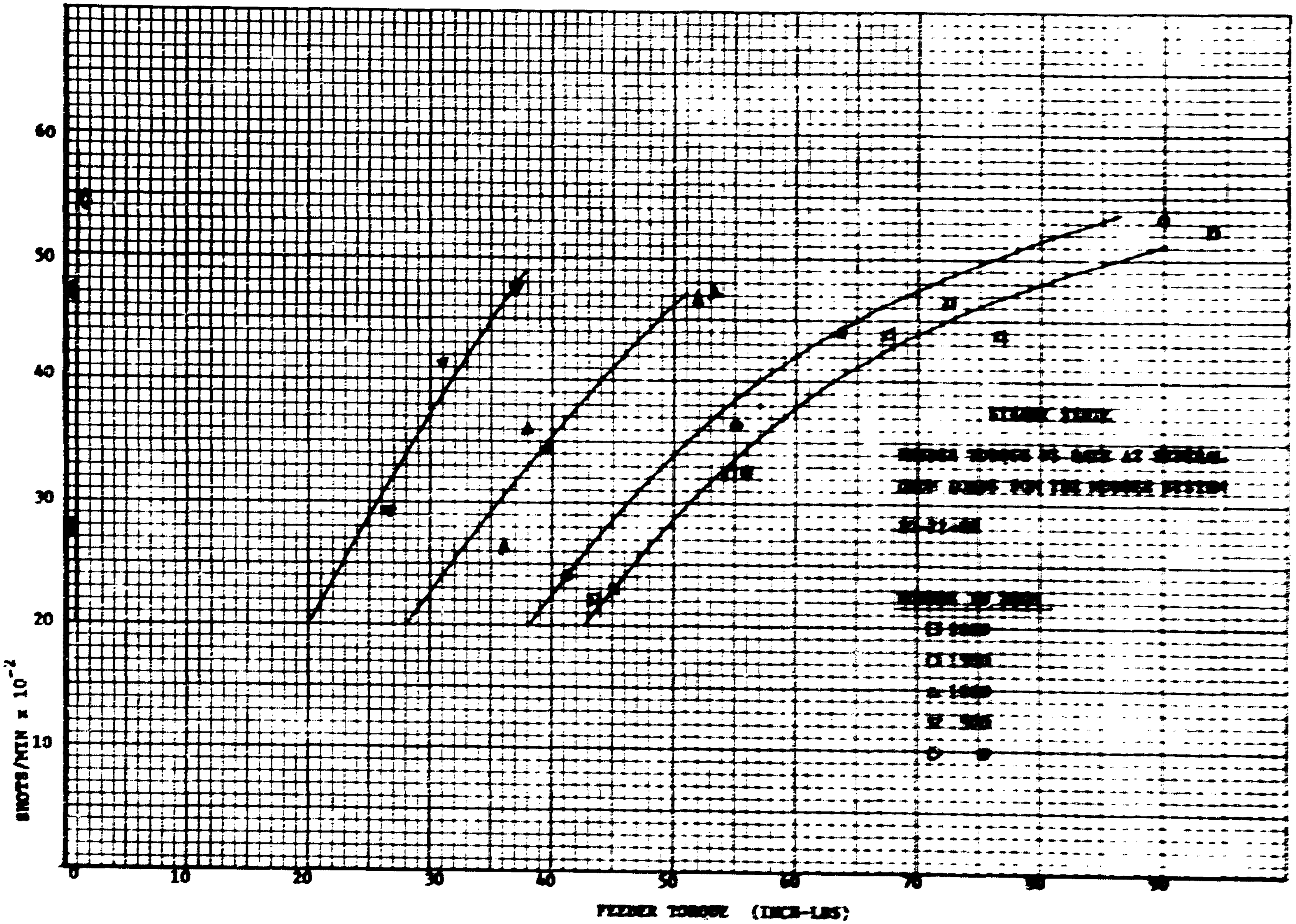


Figure 59. Steady State Feeder Torque vs Rate at Several Drum Loads for the Module System

B. CALCULATION OF MOMENT OF INERTIA OF THE MODULE FEED SYSTEM (ASSUMED LUMPED IN THE DRUM)

A standard M 80 round 7.62 mm caliber weighs 392 grains and is 2.80 inches long.

The moment of inertia about a transverse axis at 1.22 inches from the base of the round may be calculated as follows:

The density between the base and the 1.22-inch dimension and the density between the 1.22-inch dimension and the tip are each considered to be different but uniform. For the base section $\left(\frac{dM}{dr}\right)_b$ = 0.0259 pounds/inch and for the tip section $\left(\frac{dM}{dr}\right)_p$ = 0.0154 pounds/inch.

The moment of inertia of the round about its center of gravity transverse axis (at 1.22 inches from the base) may be calculated as follows:

$$I_o = \int_0^{1.22} r^2 dM_b + \int_0^{1.58} r^2 dM_p$$

$$I_o = \int_0^{1.22} 0.0259 r^2 dr + \int_0^{1.58} 0.0157 r^2 dr$$

$$I_o = 0.0363 \text{ in}^2 \text{lbs}$$

The distance from the transverse axis of the round to the center of the module drum is 3.855 inches so $My^2 = \left(\frac{392}{7000}\right)(3.855)^2 = 0.835$ or I per round = 0.8713 pound inch^2 per round.

Since the modulus of inertia of the Module Feed System when empty was found to be 166 inch^2 pounds, the inertia of the feed system at any particular load is then as follows:

$$I = \frac{166.0 + (\text{ROUNDS})\ (0.8713)}{(32.2)\ (144)} \quad \text{ft}^2 \text{ slugs}$$

C. SPRING CONSTANT OF THE MODULE FEED SYSTEM

The inner drum was blocked by inserting a piece of rod between the partitions. The rod extended up to the outer drum and kept the inner drum from rotating except for the deflection of the partition which the rod had bearing upon. To account for this small movement of the inner drum, a last-word indicator was installed between the inner and outer drums, and the measured rotation of the inner drum was converted to rotation between the barrels and housing and was subtracted from the measured barrel-to-housing rotation. The spring constant of the feed system from the upper end of the drum to the barrels is 3380 foot-pounds per radian at the drum.

Table VIII. Spring Constant of the Module Feed System

Load (lbs.)	Torque (in.-lbs.)	Scale (in. on Housing 1/32)	Δ1/32 Inch	Last Word Ind. In. 0.001	ΔHousing Reading (decimal)	Inner Drum θ Converted	ΔHousing -Inner Drum θ
0	0	1.2	0	0	0	0	0
1	11	2.0	0.8	0.75	0.0250	0.0040	0.0210
2	22	3.0	1.8	1.0	0.0562	0.0050	0.0512
3	33	4.0	2.8	1.1	0.0875	0.0055	0.0820
4	44	5.0	3.8	2.0	0.1190	0.0100	0.1090
5	55	6.5	4.7	2.9	0.1470	0.0140	0.1330
6	66	7.8	6.0	3.7	0.1870	0.0180	0.1690
7	77	8.8	7.0	4.2	0.2190	0.0200	0.1990
8	88	10.1	8.3	6.0	0.2600	0.0300	0.2300
9	99	11.3	9.5	7.6	0.2970	0.0380	0.2590
10	110	14.0	12.0	17.0	0.3820	0.0840	0.2980
1	2	3	4	5	6	7	8

The moment arm is 11.0 inches.

Inner Drum O.D. = 6.800 in.

-Radii on Ends of Fins = -0.12 in.
6.68 in. = Diameter to Last Word Indicator

Diameter of Gun Housing = 4.95 in.

To Convert Last Word Indicator Reading to Gun Housing

$$\text{Inner Drum Converted} = (\text{Indicator})\left(\frac{4.95}{6.68}\right)\text{ Gear Ratio} =$$

$$= \text{Column 7} = (\text{Indicator})\left(\frac{4.95}{6.68}\right)(6.67) = \text{Indicator }(4.95)$$

$$\text{Spring Constant} = K = \frac{(\Delta\text{ inch-pounds})\ (6.67)^2}{(12)\ \left(\frac{\Delta\text{ Housing}}{4.95\ \Pi}\right)(2\ \Pi)}$$

$$= \frac{(110.5)(44.5)(4.95)}{(24)\quad(0.300)} = 3380.\ \text{ft.-lbs./radian at drum}$$

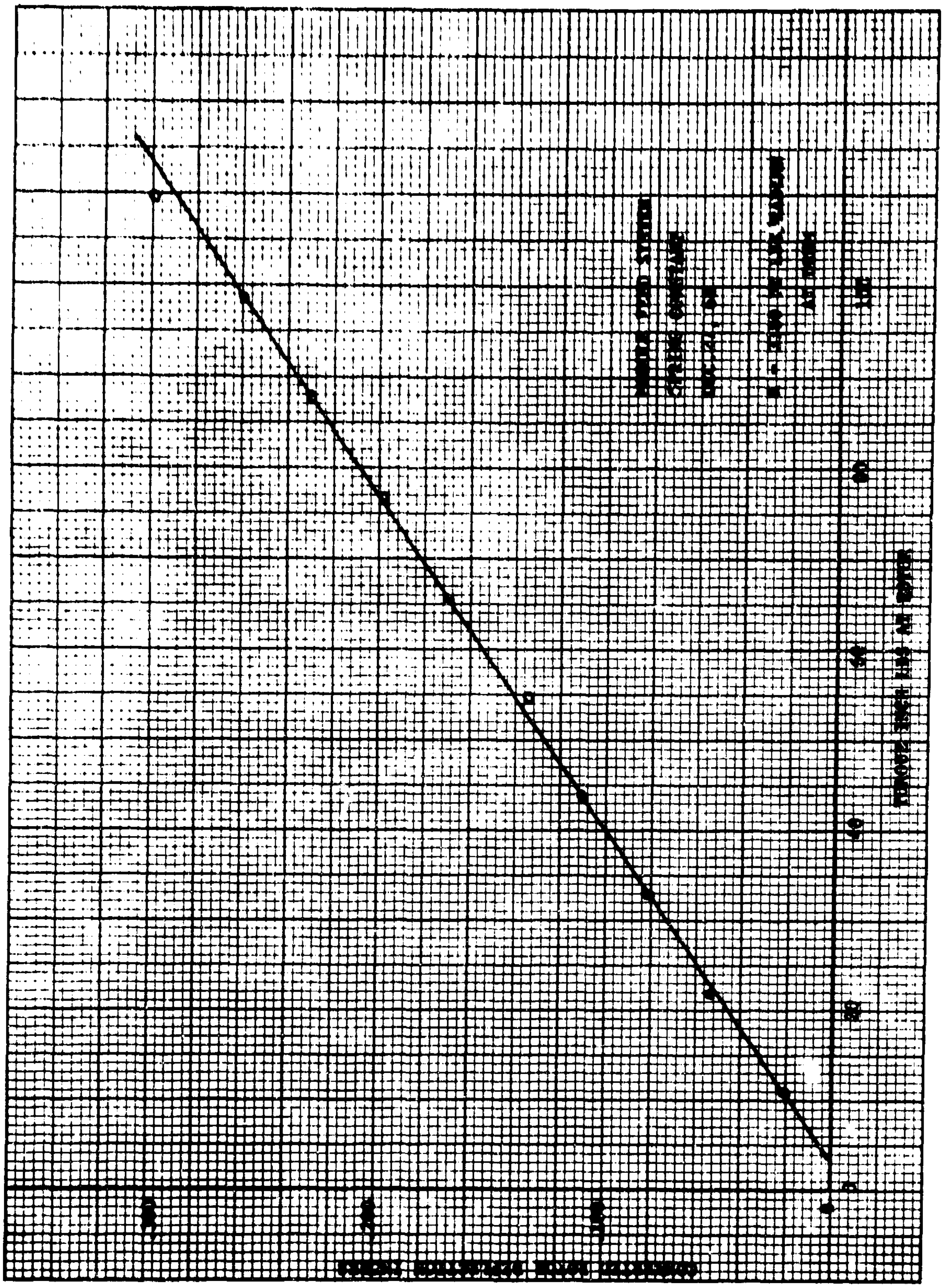


Figure 60. Module Feed System Spring Constant

D. THE SPRING CONSTANT OF THE NEW POD FEED SYSTEM

The new feeder and exit unit assembly with the new heavier parts was mounted on a pod drum assembly, and the exit gear of the exit unit assembly was blocked by inserting a screwdriver (which fitted the tooth space closely) into the exit gear teeth and fastening the screwdriver firmly to the drum assembly. A $11\frac{5}{8}$-inch arm was inserted transversely between the barrels, and weights were suspended from this arm. The rotational deflection between the rotor and housing was measured on the O.D. of the housing. The spring constant of this new pod feeder system was found to be K = 4330. foot-pounds/radian at the drum if it is assumed that there is a 40 to 6 ratio between the rotor and the inner drum.

Table IX. Spring Constant of the New Pod Feed System

Load (pounds)	Load (pounds)	Deflection at Gun Housing (32nds of inches)	Radius Arm = $11\frac{5}{8}$ inches
4.2	0	25.5	
5.2	1	26.3	
6.2	2	27.0	
7.8	3	27.8	
8.2	4	28.6	
9.2	5	29.5	
10.2	6	30.4	
11.2	7	31.0	
12.2	8	32.0	
13.2	9	32.4	
14.2	10	33.0	
15.2	11	33.2	

$$K = \frac{10 \times 11.625 \times (6.67)^2}{(12)\frac{(33.4-25.5)}{32}\;\frac{2\pi}{4.95\pi}} = 4330 \text{ ft-lbs/radian at the drum}$$

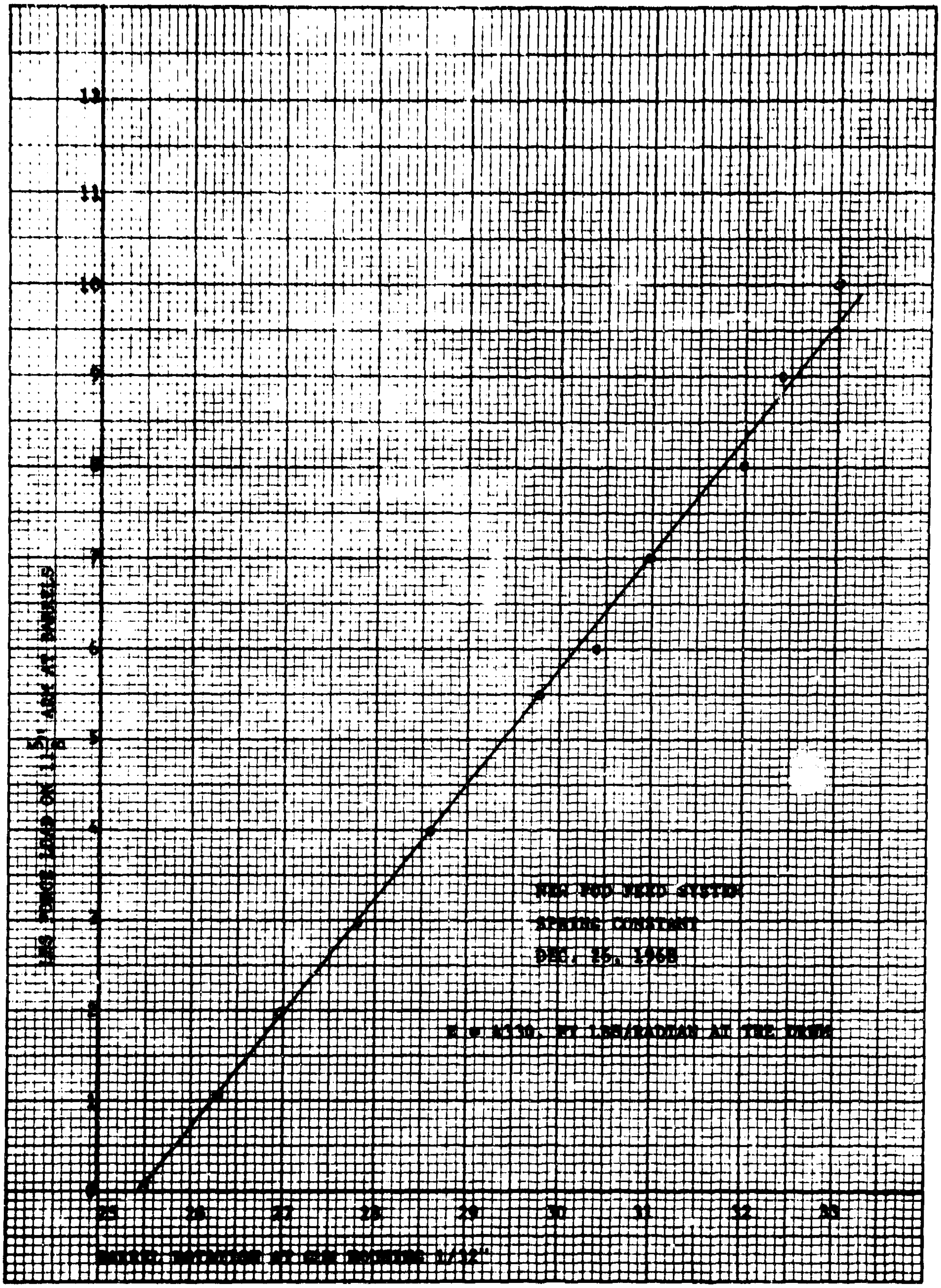


Figure 61. New Pod Feed System Spring Constant

TIME SEC	DEGREES 0	VELOCITY RAD/SEC	TOTORQUE INXLBS	FRITQUE INXLBS	SPRITQUE INXLBS	DELTQ IN.LBS	ACCL RAD/SECXSEC
0.00000E 00	0.00000E 00	0.15665E 02	-0.54134E 03	0.54134E 03	0.00000E 00	0.00000E 00	-0.10966E 03
0.20000E-02	0.17730E 01	0.15193E 02	-0.17800E 04	0.52503E 03	0.12550E 04	-0.12550E 04	-0.36059E 03
0.40000E-02	0.34637E 01	0.14233E 02	-0.29436E 04	0.49185E 03	0.24518E 04	-0.24518E 04	-0.59630E 03
0.59999E-02	0.50181E 01	0.12823E 02	-0.39952E 04	0.44313E 03	0.35521E 04	-0.35521E 04	-0.80932E 03
0.79999E-02	0.63876E 01	0.11015E 02	-0.49022E 04	0.38066E 03	0.45215E 04	-0.45215E 04	-0.99304E 03
0.99999E-02	0.75302E 01	0.88747E 01	-0.56369E 04	0.30667E 03	0.53303E 04	-0.53303E 04	-0.11418E 04
0.11999E-01	0.84118E 01	0.64744E 01	-0.61780E 04	0.22373E 03	0.59543E 04	-0.59543E 04	-0.12515E 04
0.13999E-01	0.90074E 01	0.38969E 01	-0.65106E 04	0.13466E 03	0.63759E 04	-0.63759E 04	-0.13158E 04
0.15999E-01	0.93015E 01	0.12283E 01	-0.66265E 04	0.42446E 02	0.65841E 04	-0.65841E 04	-0.13423E 04
0.17999E-01	0.92888E 01	-0.14431E 01	-0.65252E 04	-0.49868E 02	0.65751E 04	-0.65751E 04	-0.13218E 04
0.19999E-01	0.89740E 01	-0.40304E 01	-0.62130E 04	-0.13927E 03	0.63522E 04	-0.63522E 04	-0.12585E 04
0.21999E-01	0.83714E 01	-0.64506E 01	-0.57028E 04	-0.22290E 03	0.59257E 04	-0.59257E 04	-0.11552E 04
0.23999E-01	0.75048E 01	-0.86272E 01	-0.50142E 04	-0.29812E 03	0.53123E 04	-0.53123E 04	-0.10157E 04
0.25999E-01	0.64059E 01	-0.10492E 02	-0.41719E 04	-0.36258E 03	0.45345E 04	-0.45345E 04	-0.84510E 03
0.27999E-01	0.51139E 01	-0.11990E 02	-0.32055E 04	-0.41435E 03	0.36199E 04	-0.36199E 04	-0.64935E 03
0.29999E-01	0.36733E 01	-0.13077E 02	-0.21483E 04	-0.45191E 03	0.26002E 04	-0.26002E 04	-0.43518E 03
0.31999E-01	0.21333E 01	-0.13724E 02	-0.10358E 04	-0.47425E 03	0.15100E 04	-0.15100E 04	-0.20982E 03
0.33999E-01	0.54523E 00	-0.13914E 02	0.94888E 02	-0.48083E 03	0.38594E 03	-0.38594E 03	0.19221E 02
0.35999E-01	-0.10385E 01	-0.13649E 02	0.12068E 04	-0.47168E 03	-0.73511E 03	0.73511E 03	0.24446E 03
0.37999E-01	-0.25664E 01	-0.12944E 02	0.22639E 04	-0.44730E 03	-0.18166E 04	0.18166E 04	0.45861E 03
0.39999E-01	-0.39896E 01	-0.11827E 02	0.32327E 04	-0.40870E 03	-0.28240E 04	0.28240E 04	0.65486E 03
0.41999E-01	-0.52631E 01	-0.10340E 02	0.40829E 04	-0.35733E 03	-0.37255E 04	0.37255E 04	0.82707E 03
0.43999E-01	-0.63476E 01	-0.85386E 01	0.47882E 04	-0.29505E 03	-0.44932E 04	0.44932E 04	0.96996E 03
0.45999E-01	-0.72105E 01	-0.64834E 01	0.53280E 04	-0.22404E 03	-0.51040E 04	0.51040E 04	0.10793E 04
0.47999E-01	-0.78267E 01	-0.42458E 01	0.56868E 04	-0.14671E 03	-0.55401E 04	0.55401E 04	0.11519E 04
0.49999E-01	-0.81795E 01	-0.19011E 01	0.58556E 04	-0.65696E 02	-0.57899E 04	0.57899E 04	0.11861E 04
0.51999E-01	-0.82613E 01	0.47279E 00	0.58314E 04	0.16337E 02	-0.58478E 04	0.58478E 04	0.11812E 04
0.53999E-01	-0.80730E 01	0.27983E 01	0.56178E 04	0.96699E 02	-0.57145E 04	0.57145E 04	0.11380E 04
0.55999E-01	-0.76246E 01	0.50005E 01	0.52243E 04	0.17279E 03	-0.53971E 04	0.53971E 04	0.10583E 04
0.57999E-01	-0.69343E 01	0.70093E 01	0.46662E 04	0.24221E 03	-0.49085E 04	0.49085E 04	0.94525E 03
0.59999E-01	-0.60279E 01	0.87620E 01	0.39641E 04	0.30278E 03	-0.42668E 04	0.42668E 04	0.80301E 03
0.61999E-01	-0.49379E 01	0.10205E 02	0.31426E 04	0.35265E 03	-0.34953E 04	0.34953E 04	0.53651E 03
0.63999E-01	-0.37023E 01	0.11296E 02	0.22303E 04	0.39035E 03	-0.26207E 04	0.26207E 04	0.45180E 03
0.65999E-01	-0.23634E 01	0.12004E 02	0.12581E 04	0.41482E 03	-0.16729E 04	0.16729E 04	0.25486E 03
0.67999E-01	-0.96627E 00	0.12312E 02	0.25852E 03	0.42545E 03	-0.68398E 03	0.68398E 03	0.52370E 02
0.69999E-01	0.44294E 00	0.12214E 02	-0.73563E 03	0.42208E 03	0.31354E 03	-0.31354E 03	-0.14901E 03
0.71999E-01	0.18181E 01	0.11721E 02	-0.16920E 04	0.40503E 03	0.12869E 04	-0.12869E 04	-0.34275E 03
0.73999E-01	0.31150E 01	0.10852E 02	-0.25800E 04	0.37502E 03	0.22050E 04	-0.22050E 04	-0.52264E 03
0.75999E-01	0.42925E 01	0.96435E 01	-0.33717E 04	0.33323E 03	0.30385E 04	-0.30385E 04	-0.63302E 03
0.77999E-01	0.53140E 01	0.81370E 01	-0.40427E 04	0.28119E 03	0.37615E 04	-0.37615E 04	-0.81893E 03

PRESENT MODULE

ALPHA	SPM	SPCON	RONDS	PERIOD	ERTIA	CO	BETA	COPIA
90.57599	6000.00000	3380.00000	2000.00000	0.06936	0.41137	0.17295	3.50000	0.41137

Figure 62. Present Module

PRESENT MODULE

TIME	DEGREES	VELOCITY	TOTORQUE	FRITQUE	SPRITQUE	DELTQ	ACCL
SEC	0	RAD/SEC	INXLBS	INXLBS	INXLBS	INXLBS	RAD/SECXSEC
0.00000E 00	0.00000E 00	0.78328E 01	-0.27067E 03	0.27067E 03	0.00000E 00	0.00000E 00	-0.54830E 02
0.20000E-02	0.88652E 00	0.75968E 01	-0.89004E 03	0.26251E 03	0.62752E 03	-0.62752E 03	-0.18029E 03
0.40000E-02	0.17318E 01	0.71167E 01	-0.14718E 04	0.24592E 03	0.12259E 04	-0.12259E 04	-0.29815E 03
0.59999E-02	0.25090E 01	0.64118E 01	-0.19976E 04	0.22156E 03	0.17760E 04	-0.17760E 04	-0.40466E 03
0.79999E-02	0.31938E 01	0.55079E 01	-0.24511E 04	0.19033E 03	0.22607E 04	-0.22607E 04	-0.49652E 03
0.99999E-02	0.37651E 01	0.44373E 01	-0.28184E 04	0.15333E 03	0.26651E 04	-0.26651E 04	-0.57094E 03
0.11999E-01	0.42059E 01	0.32372E 01	-0.30890E 04	0.11186E 03	0.29771E 04	-0.29771E 04	-0.62575E 03
0.13999E-01	0.45037E 01	0.19484E 01	-0.32553E 04	0.67330E 02	0.31879E 04	-0.31879E 04	-0.65942E 03
0.15999E-01	0.46507E 01	0.61416E 00	-0.33132E 04	0.21223E 02	0.32920E 04	-0.32920E 04	-0.67117E 03
0.17999E-01	0.46444E 01	-0.72156E 00	-0.32626E 04	-0.24934E 02	0.32875E 04	-0.32875E 04	-0.66091E 03
0.19999E-01	0.44870E 01	-0.20152E 01	-0.31065E 04	-0.69638E 02	0.31761E 04	-0.31761E 04	-0.62928E 03
0.21999E-01	0.41857E 01	-0.32253E 01	-0.28514E 04	-0.11145E 03	0.29628E 04	-0.29628E 04	-0.57761E 03
0.23999E-01	0.37524E 01	-0.43136E 01	-0.25071E 04	-0.14906E 03	0.26561E 04	-0.26561E 04	-0.50786E 03
0.25999E-01	0.32029E 01	-0.52464E 01	-0.20859E 04	-0.18129E 03	0.22672E 04	-0.22672E 04	-0.42255E 03
0.27999E-01	0.25569E 01	-0.59954E 01	-0.16027E 04	-0.20717E 03	0.18099E 04	-0.18099E 04	-0.32467E 03
0.29999E-01	0.18366E 01	-0.65389E 01	-0.10741E 04	-0.22595E 03	0.13001E 04	-0.13001E 04	-0.21759E 03
0.31999E-01	0.10666E 01	-0.68620E 01	-0.51791E 03	-0.23712E 03	0.75504E 03	-0.75504E 03	-0.10491E 03
0.33999E-01	0.27261E 00	-0.69573E 01	0.47444E 02	-0.24041E 03	0.19297E 03	-0.19297E 03	0.96107E 01
0.35999E-01	-0.51925E 00	-0.68249E 01	0.60340E 03	-0.23584E 03	-0.36755E 03	0.36755E 03	0.12223E 03
0.37999E-01	-0.12832E 01	-0.64721E 01	0.11319E 04	-0.22365E 03	-0.90833E 03	0.90833E 03	0.22930E 03
0.39999E-01	-0.19948E 01	-0.59136E 01	0.16163E 04	-0.20435E 03	-0.14120E 04	0.14120E 04	0.32743E 03
0.41999E-01	-0.26315E 01	-0.51704E 01	0.20414E 04	-0.17866E 03	-0.18627E 04	0.18627E 04	0.41353E 03
0.43999E-01	-0.31738E 01	-0.42693E 01	0.23941E 04	-0.14752E 03	-0.22466E 04	0.22466E 04	0.48498E 03
0.45999E-01	-0.36052E 01	-0.32417E 01	0.26640E 04	-0.11202E 03	-0.25520E 04	0.25520E 04	0.53965E 03
0.47999E-01	-0.39133E 01	-0.21229E 01	0.28434E 04	-0.73359E 02	-0.27700E 04	0.27700E 04	0.57599E 03
0.49999E-01	-0.40897E 01	-0.95058E 00	0.29278E 04	-0.32848E 02	-0.28949E 04	0.28949E 04	0.59309E 03
0.51999E-01	-0.41306E 01	0.23639E 00	0.29157E 04	0.81689E 01	-0.29239E 04	0.29239E 04	0.59064E 03
0.53999E-01	-0.40365E 01	0.13991E 01	0.28089E 04	0.48349E 02	-0.28572E 04	0.28572E 04	0.56900E 03
0.55999E-01	-0.38123E 01	0.25002E 01	0.26121E 04	0.86398E 02	-0.26985E 04	0.26985E 04	0.52915E 03
0.57999E-01	-0.34671E 01	0.35046E 01	0.23331E 04	0.12110E 03	-0.24542E 04	0.24542E 04	0.47262E 03
0.59999E-01	-0.30139E 01	0.43810E 01	0.19820E 04	0.15139E 03	-0.21334E 04	0.21334E 04	0.40150E 03
0.61999E-01	-0.24689E 01	0.51026E 01	0.15713E 04	0.17632E 03	-0.17476E 04	0.17476E 04	0.31930E 03
0.63999E-01	-0.18511E 01	0.56481E 01	0.11151E 04	0.19517E 03	-0.13103E 04	0.13103E 04	0.22590E 03
0.65999E-01	-0.11817E 01	0.60022E 01	0.62908E 03	0.20741E 03	-0.83649E 03	0.83649E 03	0.12743E 03
0.67999E-01	-0.48313E 00	0.61560E 01	0.12926E 03	0.21272E 03	-0.34199E 03	0.34199E 03	0.26185E 02
0.69999E-01	0.22147E 00	0.61073E 01	-0.36781E 03	0.21104E 03	0.15677E 03	-0.15677E 03	-0.74508E 02
0.71999E-01	0.90908E 00	0.58605E 01	-0.84601E 03	0.20251E 03	0.64349E 03	-0.64349E 03	-0.17137E 03
0.73999E-01	0.15575E 01	0.54264E 01	-0.12900E 04	0.18751E 03	0.11025E 04	-0.11025E 04	-0.26132E 03
0.75999E-01	0.21462E 01	0.48217E 01	-0.16858E 04	0.16661E 03	0.15192E 04	-0.15192E 04	-0.34151E 03
0.77999E-01	0.26570E 01	0.40685E 01	-0.20213E 04	0.14059E 03	0.18807E 04	-0.18807E 04	-0.40946E 03

ALPHA	SPM	SPCON	RONDS	PERIOD	ERTIA	CO	BETA	COPIA
90.57599	3000.00000	3380.00000	2000.00000	0.06936	0.41137	0.08647	3.50000	0.41137

Figure 63. Present Module

TIME SEC	DEGREES	VELOCITY RAD/SEC	TOTORQUE INXLBS	FRITQUE INXLBS	SPRITQUE INXLBS	DELTQ INXLBS	ACCL RAD/SECXSEC
[illegible]	[illegible]	0.15665E 02	-0.12197E 04	0.12197E 04	[illegible]	[illegible]	[illegible].16449E 03
[illegible]	0.17682E 01	0.15124E 02	-0.27811E 04	0.11776E 04	0.16034E 04	-0.16034E 04	-0.375[illegible]E 03
[illegible]	0.34509E 01	0.14175E 02	-0.42830E 04	0.11037E 04	0.31293E 04	-0.31293E 04	-0.57083E 03
[illegible]	0.50090E 01	0.12854E 02	-0.55376E 04	0.10008E 04	0.45368E 04	-0.45368E 04	-0.74676E 03
[illegible]	0.63865E 01	0.11204E 02	-0.66619E 04	0.97742E 03	0.57895E 04	-0.57[illegible]95E 04	-0.89038E 03
[illegible]	0.79606E 01	0.92793E 01	-0.75785E 04	0.72751E 03	0.68960E 04	-0.68[illegible]60E 04	-0.10219E 04
[illegible]	0.85090E 01	0.71372E 01	-0.82663E 04	0.55579E 03	0.77106E 04	-0.77[illegible]06E 04	-0.11147E 04
[illegible]	0.91086E 01	0.49422E 01	-0.87111E 04	0.37703E 03	0.83341E 04	-0.83[illegible]41E 04	-0.11747E 04
[illegible]	0.96096E 01	0.24609E 01	-0.90056E 04	0.19161E 03	0.87140E 04	-0.87[illegible]40E 04	-0.12[illegible]9E 04
[illegible]	0.97539E 01	0.61007E-01	-0.98497E 04	0.47498E 01	0.88449E 04	-0.88449E 04	-0.11934E 04
[illegible]	0.96256E 01	-0.22907E 01	-0.85500E 04	-0.17836E 03	0.87284E 04	-0.87284E 04	-0.11529E 04
[illegible]	0.92332E 01	-0.45302E 01	-0.82200E 04	-0.35273E 03	0.83727E 04	-0.83727E 04	-0.10815E 04
[illegible]	0.85986E 01	-0.65978E 01	-0.72790E 04	-0.51372E 03	0.77928E 04	-0.77928E 04	-0.99161E 03
[illegible]	0.77296E 01	-0.84304E 01	-0.63521E 04	-0.65715E 03	0.70092E 04	-0.70[illegible]92E 04	-0.85659E 03
[illegible]	0.65696E 01	-0.10010E 02	-0.52696E 04	-0.77942E 03	0.61480E 04	-0.61480E 04	-0.71049E 03
[illegible]	0.54471E 01	-0.1127[illegible]E 02	-0.40619E 04	-0.87757E 03	0.49395E 04	-0.49395E 04	-0.54776E 03
[illegible]	0.40903E 01	-0.12193E 02	-0.27678E 04	-0.94941E 03	0.37172E 04	-0.37172E 04	-0.37325E 03
[illegible]	0.24660E 01	-0.12758E 02	-0.14241E 04	-0.99349E 03	0.24176E 04	-0.24176E 04	-0.19206E 03
[illegible]	0.11983E 01	-0.12956E 02	-0.68903E 02	-0.10091E 04	0.10790E 04	-0.10790E 04	-0.92917E 01
[illegible]	-0.29058E 00	-0.12796E 02	0.12600E 04	-0.99655E 03	-0.26351E [illegible]	0.26351E 03	0.16992E 03
[illegible]	-0.17812E 01	-0.12286E 02	0.25245E 04	-0.95665E 03	-0.15699E 04	0.15699E 04	0.34071E 03
[illegible]	-0.30947E 01	-0.11444E 02	0.36969E 04	-0.89111E 03	-0.28057E 04	0.28057E 04	0.49852E 03
[illegible]	-0.43420E 01	-0.10303E 02	0.47404E 04	-0.80728E 03	-0.39381E 04	0.39381E 04	0.63926E 03
[illegible]	-0.54456E 01	-0.89013E 01	0.56312E 04	-0.69808E 03	-0.49381E 04	0.49381E 04	0.75998E 03
[illegible]	-0.63768E 01	-0.72916E 01	0.63477E 04	-0.55698E 03	-0.57827E 04	0.57827E 04	0.856[illegible]E 03
[illegible]	-0.71082E 01	-0.54945E 01	0.58776E 04	-0.42792E 03	-0.64458E 04	0.64458E 04	0.92692E 03
[illegible]	-0.74297E 01	-0.35922E 01	0.71984E 04	-0.27070E 03	-0.69187E 04	0.69187E 04	0.97372E 03
[illegible]	-0.78293E 01	-0.16301E 01	0.73172E 04	-0.12692E 03	-0.71903E 04	0.71903E 04	0.98675E 03
[illegible]	-0.80032E 01	0.37629E 00	0.72812E 04	0.28184E 02	-0.72573E 04	0.72573E 04	0.97514E 03
[illegible]	-0.78841E 01	0.22525E 01	0.69468E 04	0.17559E 03	-0.71227E 04	0.71227E 04	0.93579E 03
[illegible]	-0.74908E 01	0.40644E 01	0.64761E 04	0.31654E 03	-0.67927E 04	0.67927E 04	0.87331E 03
[illegible]	-0.69278E 01	0.57306E 01	0.58309E 04	0.44620E 03	-0.62821E 04	0.62821E 04	0.79699E 03
[illegible]	-0.61867E 01	0.72213E 01	0.50476E 04	0.56071E 03	-0.56084E 04	0.56084E 04	0.69769E 03
[illegible]	-0.52960E 01	0.84472E 01	0.41363E 04	0.65736E 03	-0.47934E 04	0.47934E 04	0.55776E 03
[illegible]	-0.42597E 01	0.94737E 01	0.31299E 04	0.73376E 03	-0.38627E 04	0.38627E 04	0.42195E 03
[illegible]	-0.31358E 01	0.10124E 02	0.20562E 04	0.78029E 03	-0.28445E 04	0.28445E 04	0.27729E 03
[illegible]	-0.19505E 01	0.10529E 02	0.96800E 03	0.81088E 03	-0.17587E 04	0.17587E 04	0.12795E 03
[illegible]	[illegible]	0.10675E 02	-0.16171E 03	0.82913E 03	-0.66641E 03	0.66641E 03	-0.21907E 02
[illegible]	0.475[illegible]E 00	0.10445E 02	-0.12447E 04	0.81328E 03	0.43147E 03	-0.43[illegible]47E 03	-0.16785E 03
[illegible]	0.16442E 01	0.99694E 01	-0.22708E 04	0.77624E 03	0.14946E 04	-0.14946E 04	-0.30622E 03

NOT REPRODUCIBLE

[illegible]	[illegible]	[illegible]	[illegible]	PERIOD	ERTIA	CD	BETA	CORIA
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.61796	[illegible]	[illegible]	[illegible]

Figure 64. New Pod

TIME	DEGREES	VELOCITY	TOTORQUE	FRITQUE	SPRITQUE	DELTQ	ACCL
SEC	0	RAD/SEC	INXLBS	INXLBS	INXLBS	INXLBS	RAD/SECXSEC

NEW POD

[illegible]E-03	[illegible]	0.78328E 01	-0.60989E 03	0.60989E 03	0.00000E 00	0.00000E 00	-0.82245E 02
[illegible]E-02	0.88614E 01	0.75621E 01	-0.13905E 04	0.58881E 03	0.80174E 03	-0.80174E 03	-0.18751E 03
[illegible]E-02	0.17254E 01	0.70877E 01	-0.21165E 04	0.55187E 03	0.15646E 04	-0.15646E 04	-0.28961E 03
0.50000E-02	0.25019E 01	0.66270E 01	-0.27688E 04	0.50063E 03	0.22684E 04	-0.22684E 04	-0.37330E 03
0.70000E-02	0.31922E 01	0.56039E 01	-0.33309E 04	0.43621E 03	0.28947E 04	-0.28947E 04	-0.44919E 03
0.90000E-02	0.37939E 01	0.46396E 01	-0.37092E 04	0.36125E 03	0.34280E 04	-0.34280E 04	-0.51099E 03
0.11000E-01	0.42515E 01	0.35686E 01	-0.41331E 04	0.27786E 03	0.38553E 04	-0.38553E 04	-0.55736E 03
0.13000E-01	0.45953E 01	0.24211E 01	-0.43555E 04	0.18851E 03	0.41670E 04	-0.41670E 04	-0.58736E 03
0.15000E-01	0.48048E 01	0.12324E 01	-0.44528E 04	0.95808E 02	0.43570E 04	-0.43570E 04	-0.60047E 03
0.17000E-01	0.48769E 01	0.90591E-01	-0.44248E 04	0.29749E 01	0.44224E 04	-0.44224E 04	-0.59670E 03
0.19000E-01	0.48127E 01	-0.11453E 01	-0.42750E 04	-0.89182E 02	0.43642E 04	-0.43642E 04	-0.57649E 03
0.21000E-01	0.46166E 01	-0.22651E 01	-0.40100E 04	-0.17636E 03	0.41863E 04	-0.41863E 04	-0.54075E 03
0.23000E-01	0.42968E 01	-0.32989E 01	-0.36395E 04	-0.25686E 03	0.38964E 04	-0.38964E 04	-0.49080E 03
0.25000E-01	0.38644E 01	-0.42109E 01	-0.31760E 04	-0.32857E 03	0.35046E 04	-0.35046E 04	-0.42829E 03
0.27000E-01	0.33348E 01	-0.50053E 01	-0.26363E 04	-0.38971E 03	0.30240E 04	-0.30240E 04	-0.35524E 03
0.29000E-01	0.27235E 01	-0.56953E 01	-0.20309E 04	-0.43878E 03	0.24697E 04	-0.24697E 04	-0.27388E 03
0.31000E-01	0.20496E 01	-0.60966E 01	-0.13839E 04	-0.47470E 03	0.18586E 04	-0.18586E 04	-0.18662E 03
0.33000E-01	0.13330E 01	-0.63796E 01	-0.71206E 03	-0.49676E 03	0.12088E 04	-0.12088E 04	-0.96023E 02
0.35000E-01	0.59462E 00	-0.64817E 01	-0.94451E 02	-0.50457E 03	0.53902E 03	-0.53902E 03	-0.46458E 01
0.37000E-01	-0.14525E 00	-0.63994E 01	0.63203E 03	-0.49827E 03	-0.13175E 03	0.13175E 03	0.84961E 02
0.39000E-01	-0.86562E 00	-0.61432E 01	0.12632E 04	-0.47832E 03	-0.78495E 03	0.78495E 03	0.17035E 03
0.41000E-01	-0.15677E 01	-0.57223E 01	0.18484E 04	-0.44595E 03	-0.14028E 04	0.14028E 04	0.24926E 03
0.43000E-01	-0.21714E 01	-0.51519E 01	0.23702E 04	-0.40114E 03	-0.19690E 04	0.19690E 04	0.31963E 03
0.45000E-01	-0.27279E 01	-0.44506E 01	0.28156E 04	-0.34694E 03	-0.24690E 04	0.24690E 04	0.37969E 03
0.47000E-01	-0.31874E 01	-0.36409E 01	0.31738E 04	-0.28349E 03	-0.28903E 04	0.28903E 04	0.42800E 03
0.49000E-01	-0.35541E 01	-0.27472E 01	0.34368E 04	-0.21391E 03	-0.32229E 04	0.32229E 04	0.46346E 03
0.51000E-01	-0.38148E 01	-0.17961E 01	0.35992E 04	-0.13985E 03	-0.34593E 04	0.34593E 04	0.48536E 03
0.53000E-01	-0.39646E 01	-0.91537E 00	0.36586E 04	-0.63464E 02	-0.35951E 04	0.35951E 04	0.49337E 03
0.55000E-01	-0.40016E 01	0.16814E 00	0.36156E 04	0.13092E 02	-0.36286E 04	0.36286E 04	0.48757E 03
0.57000E-01	-0.39270E 01	0.11252E 01	0.34734E 04	0.87696E 02	-0.35611E 04	0.35611E 04	0.46839E 03
0.59000E-01	-0.37456E 01	0.20332E 01	0.32380E 04	0.15832E 03	-0.33963E 04	0.33963E 04	0.43665E 03
0.61000E-01	-0.34638E 01	0.28652E 01	0.29179E 04	0.22310E 03	-0.31410E 04	0.31410E 04	0.39349E 03
0.63550E-01	-0.31523E 01	0.36206E 01	0.25238E 04	0.28035E 03	-0.28042E 04	0.28042E 04	0.34034E 03
0.65599E-01	-0.25430E 01	0.42211E 01	0.20680E 04	0.32857E 03	-0.23967E 04	0.23967E 04	0.27088E 03
0.67950E-01	-0.21728E 01	0.47115E 01	0.15644E 04	0.36688E 03	-0.19313E 04	0.19313E 04	0.21097E 03
0.69000E-01	-0.15696E 01	0.50627E 01	0.10281E 04	0.39414E 03	-0.14222E 04	0.14222E 04	0.13964E 03
0.71000E-01	-0.97577E 00	0.52649E 01	0.47444E 03	0.40994E 03	-0.88438E 03	0.88438E 03	0.53979E 02
0.73000E-01	-0.36745E 00	0.53170E 01	-0.82857E 02	0.41476E 03	-0.33321E 03	0.33321E 03	-0.10903E 02
0.75999E-01	0.23790E 00	0.52275E 01	-0.67238E 03	0.40664E 03	0.21573E 03	-0.21573E 03	-0.83929E 02
0.77000E-01	0.82410E 00	0.49547E 01	-0.11354E 04	0.38812E 03	0.74730E 03	-0.74730E 03	-0.15211E 03

TIME	SP?	SPCO?	POUNDS	PERIOD	FRTIA	CO	BETA	COPIA
[illegible]475	[illegible]	337.[illegible]	31[illegible]	0.[illegible]752[illegible]	0.61796	0.[illegible]9375	5.25[illegible]	0.61796

Figure 65. New Pod

Table X. Potentiometer Settings for Analog Computer

Pot.	$\phi/20$ Po 1	K/10000I Qo 1	I Po 2	$\frac{I}{5}$ Po 3	$Kx10^{-4}$ Qo 3	2B/20 Qo 4
	3930.0	0.8000	0.4120	0.0825	3380.0	0.0400
	3930.0	0.5460	0.6180	1,2360	3380.0	0.0400
	7860.0	0.5460	0.6180	1.2360	3380.0	0.0400
	7860.0	0.7000	0.6180	1.2360	4330.0	0.0400
	3930.0	0.7000	0.6180	1.2360	4330.0	0.0400
	3930.0	0.7000	0.6180	1.2360	4330.0	0.0500
	7860.0	0.7000	0.6180	1.2360	4330.0	0.0500
	7860.0	0.5460	0.6180	1.2360	3380.0	0.0500
	3930.0	0.5460	0.6180	1.2360	3380.0	0.0500
	3930.0	0.8000	0.4120	0.0825	3380.0	0.0500
	7860.0	0.8000	0.4120	0.0825	3380.0	0.0500
	7860.0	0.8000	0.4120	0.0825	3380.0	0.0500
	7860.0	0.8000	0.4120	0.0825	3380.0	0.0300
	3930.0	0.8000	0.4120	0.0825	3380.0	0.0300
	3930.0	0.5460	0.6180	0.0236	3380.0	0.0300
	7860.0	0.5460	0.6180	0.0236	3380.0	0.0300
	7860.0	0.7000	0.6180	1.2360	4430.0	0.0300

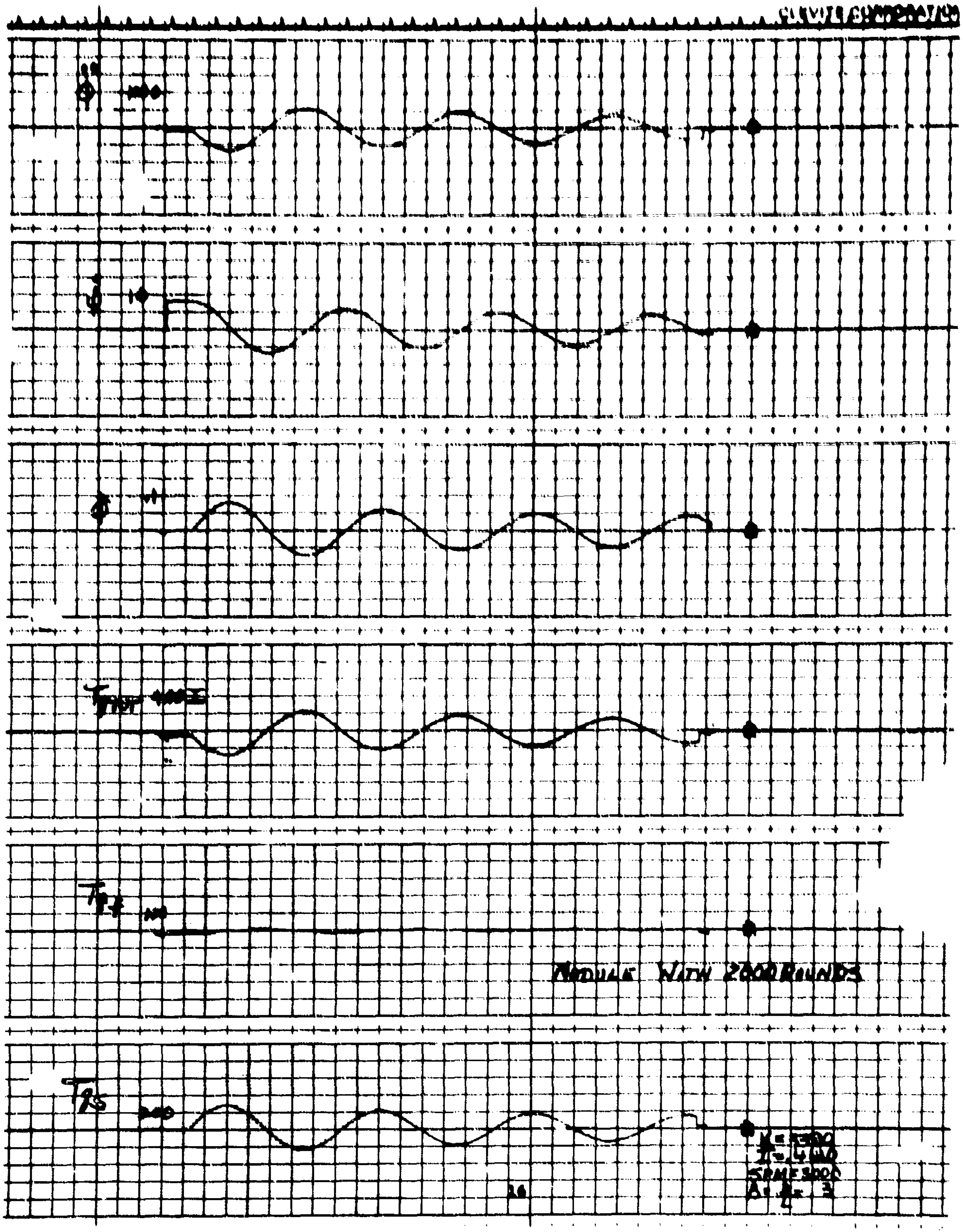


Figure 66. Module with 2000 Rounds

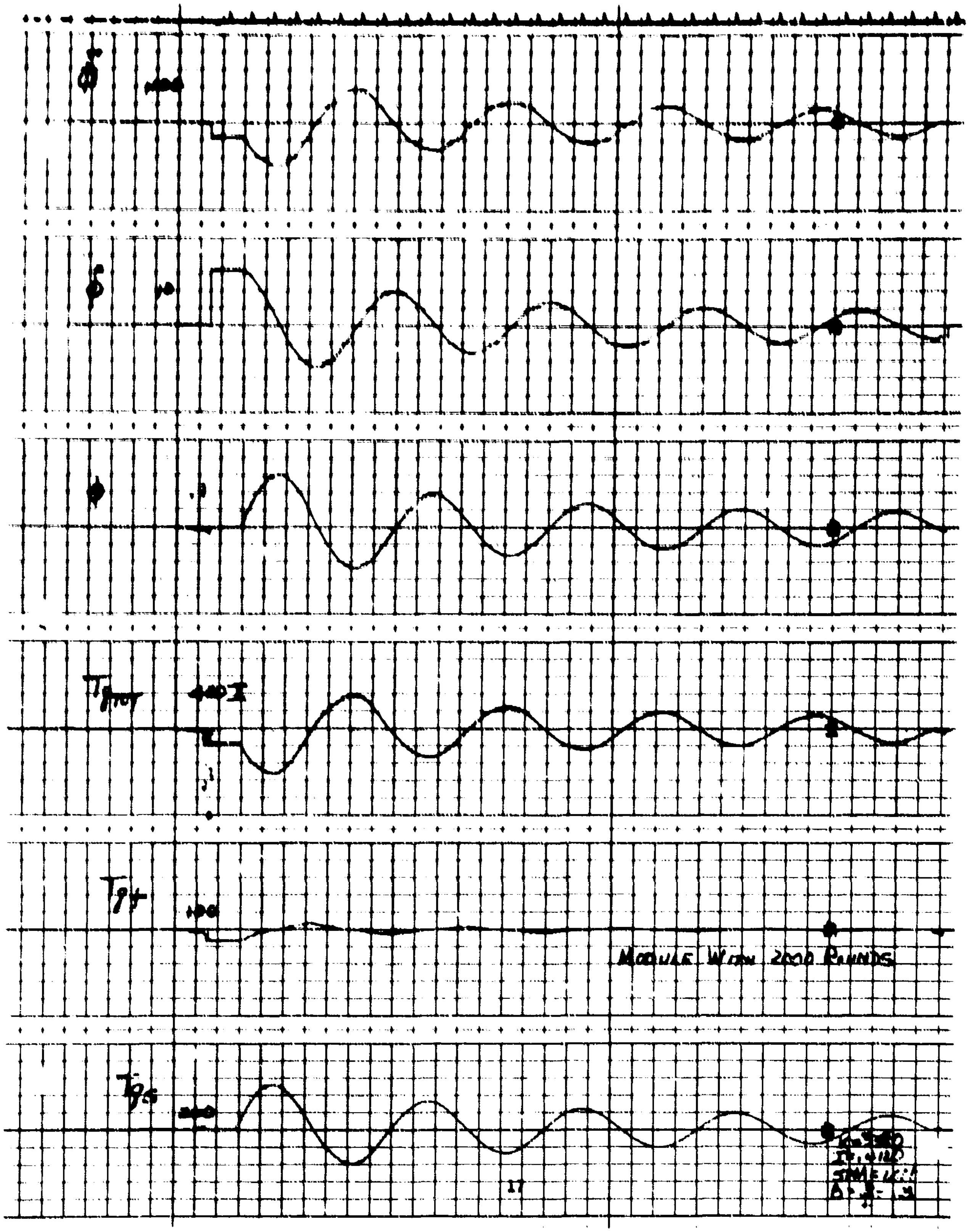


Figure 67. Module with 2000 Rounds

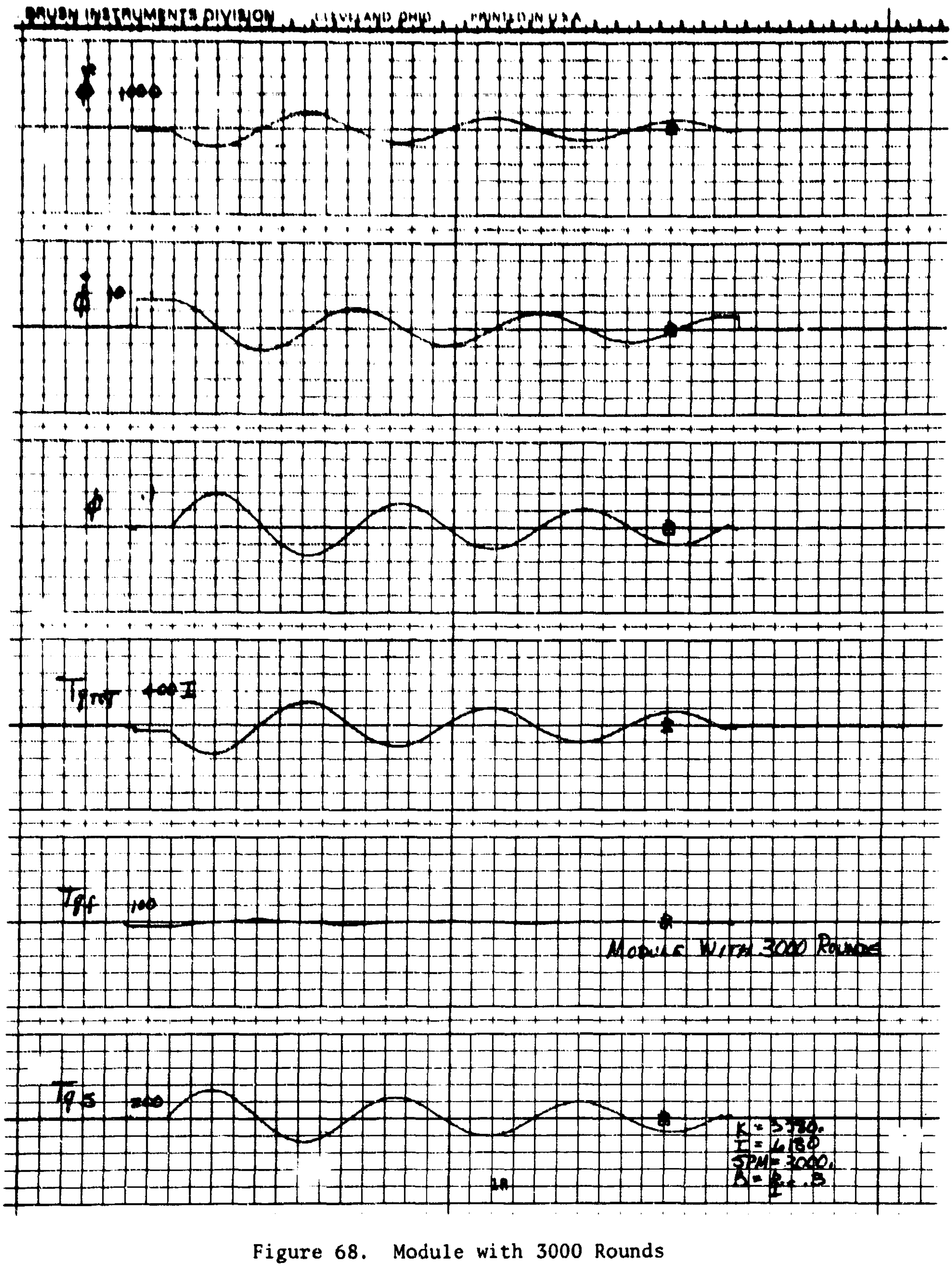


Figure 68. Module with 3000 Rounds

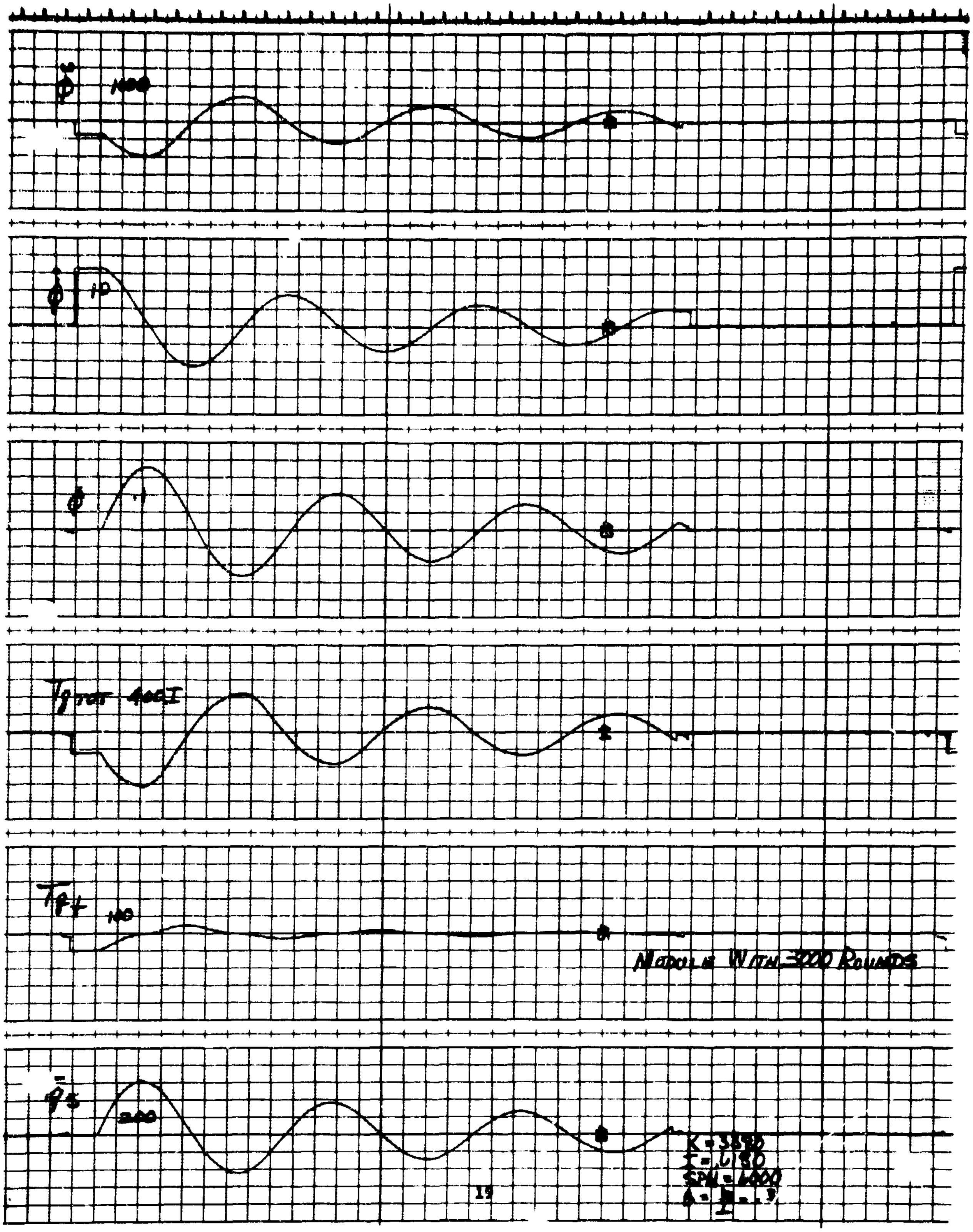


Figure 69. Module with 3000 Rounds

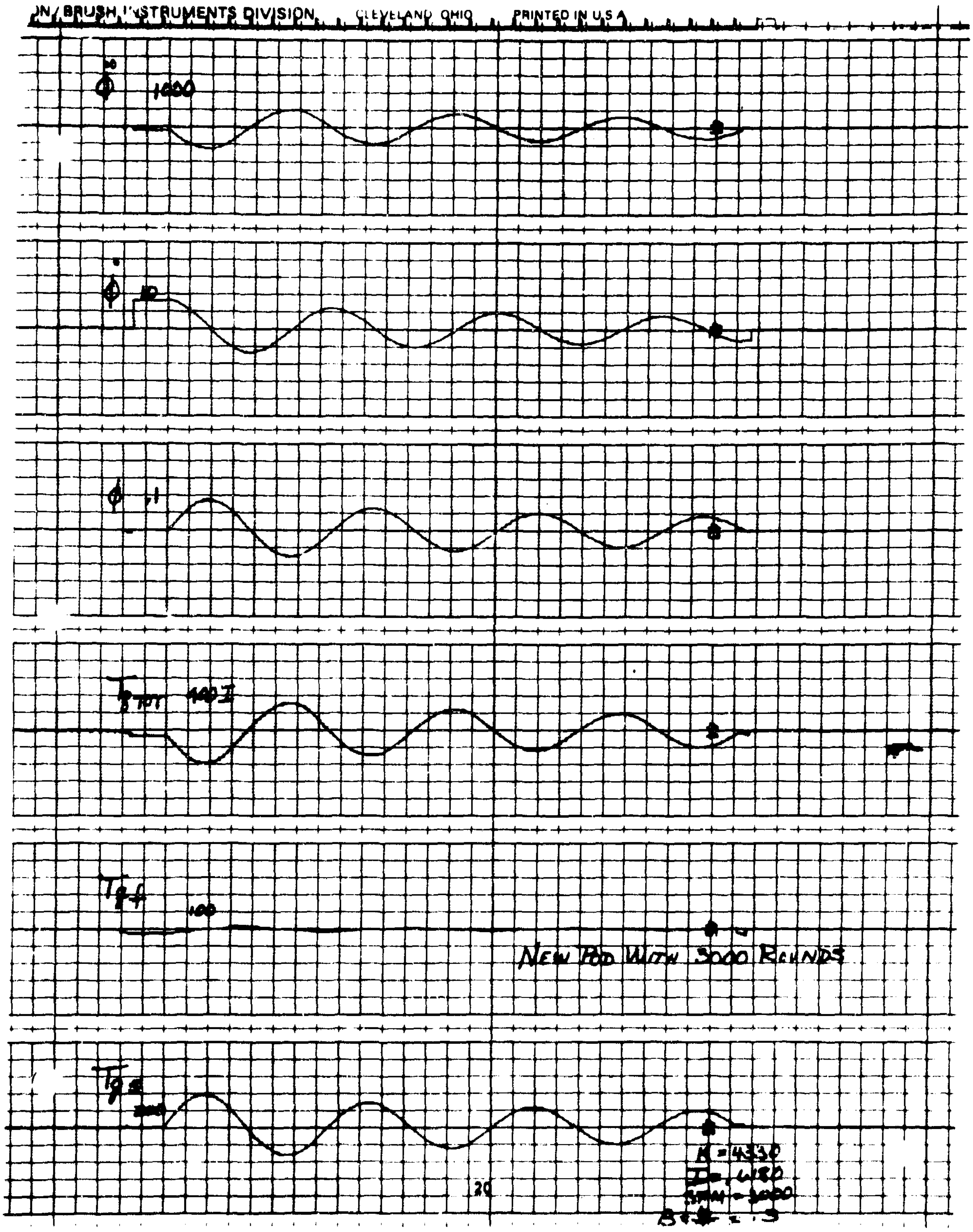


Figure 70. New Pod with 3000 Rounds

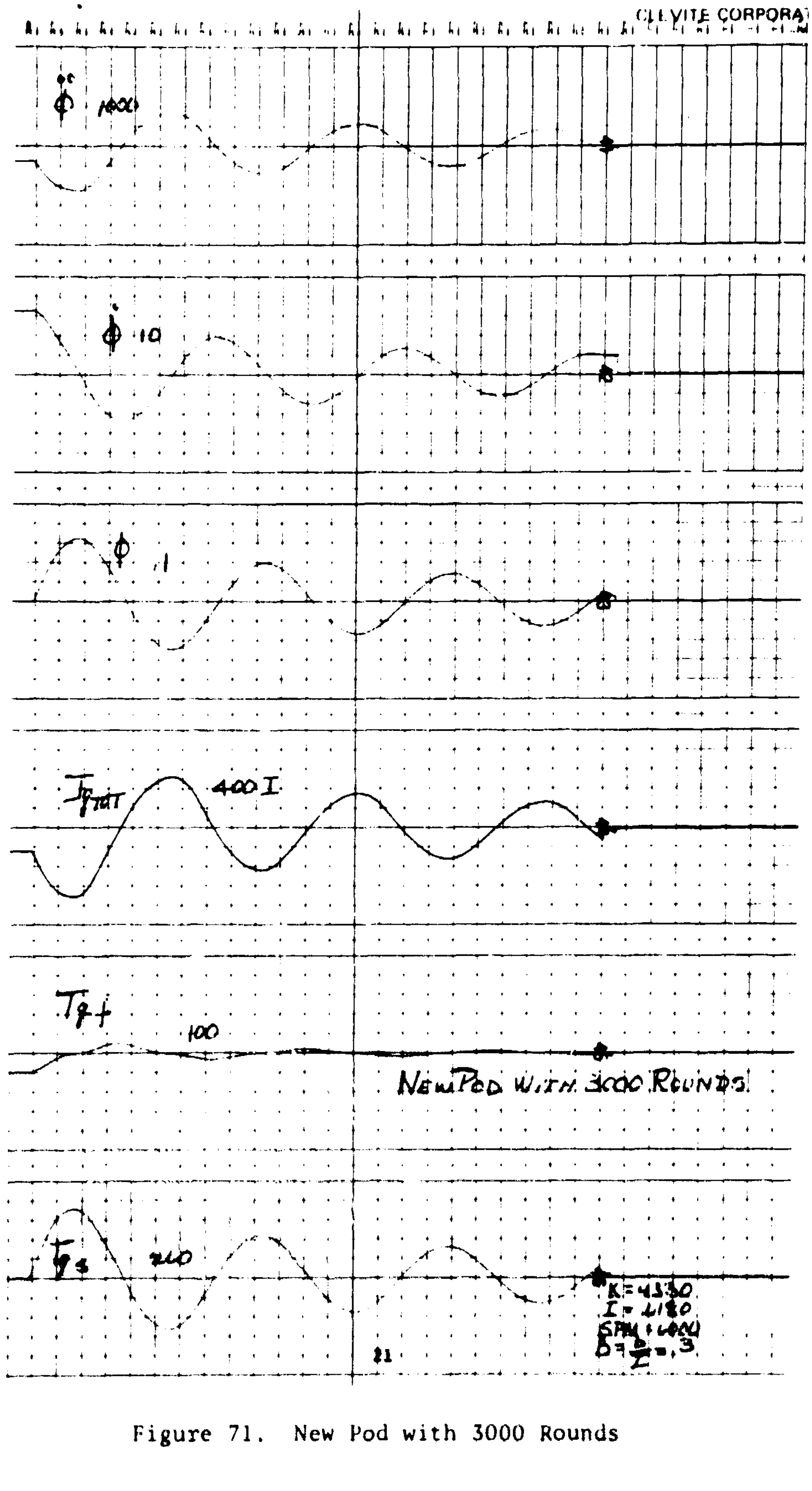


Figure 71. New Pod with 3000 Rounds

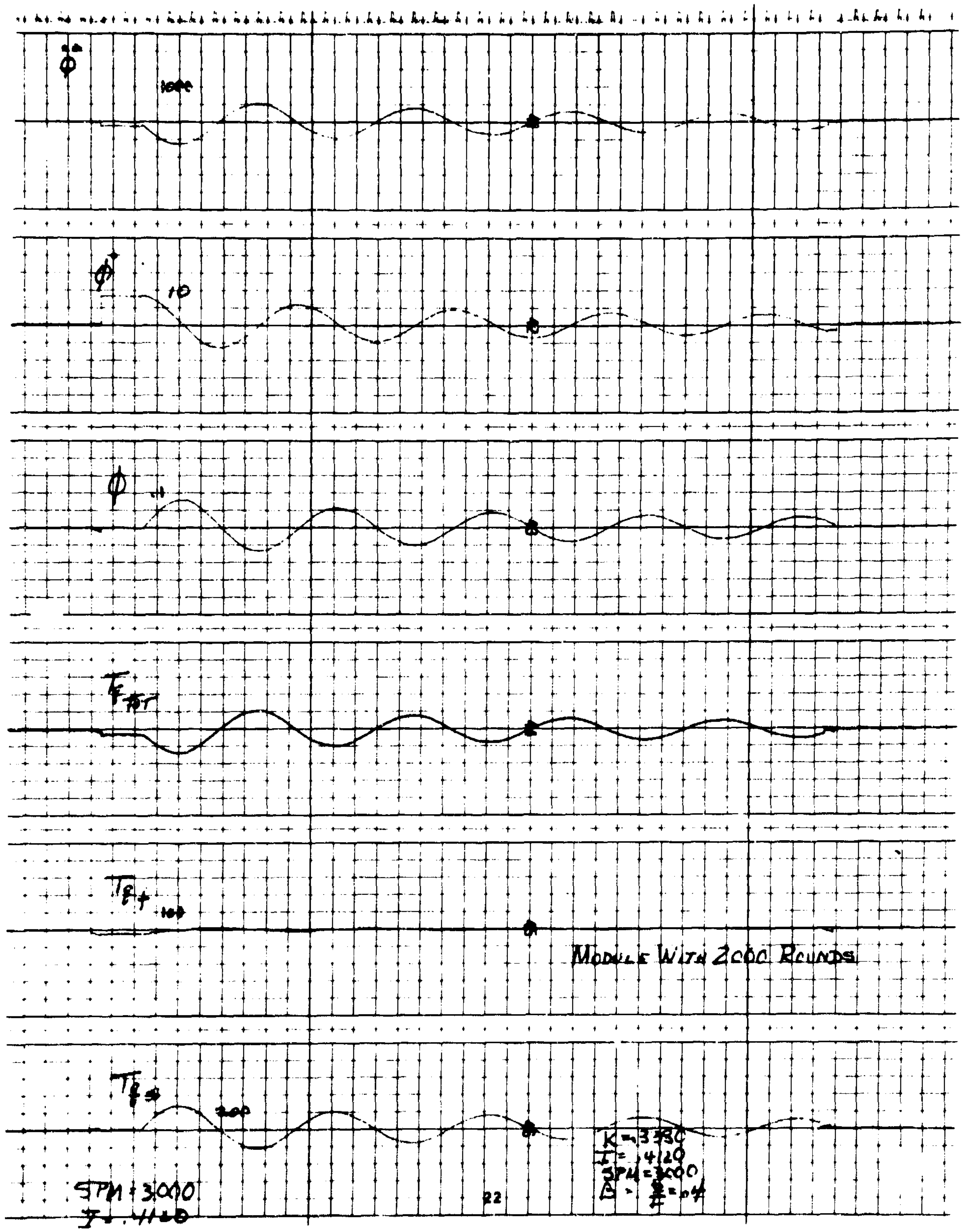


Figure 72. Module with 2000 Rounds

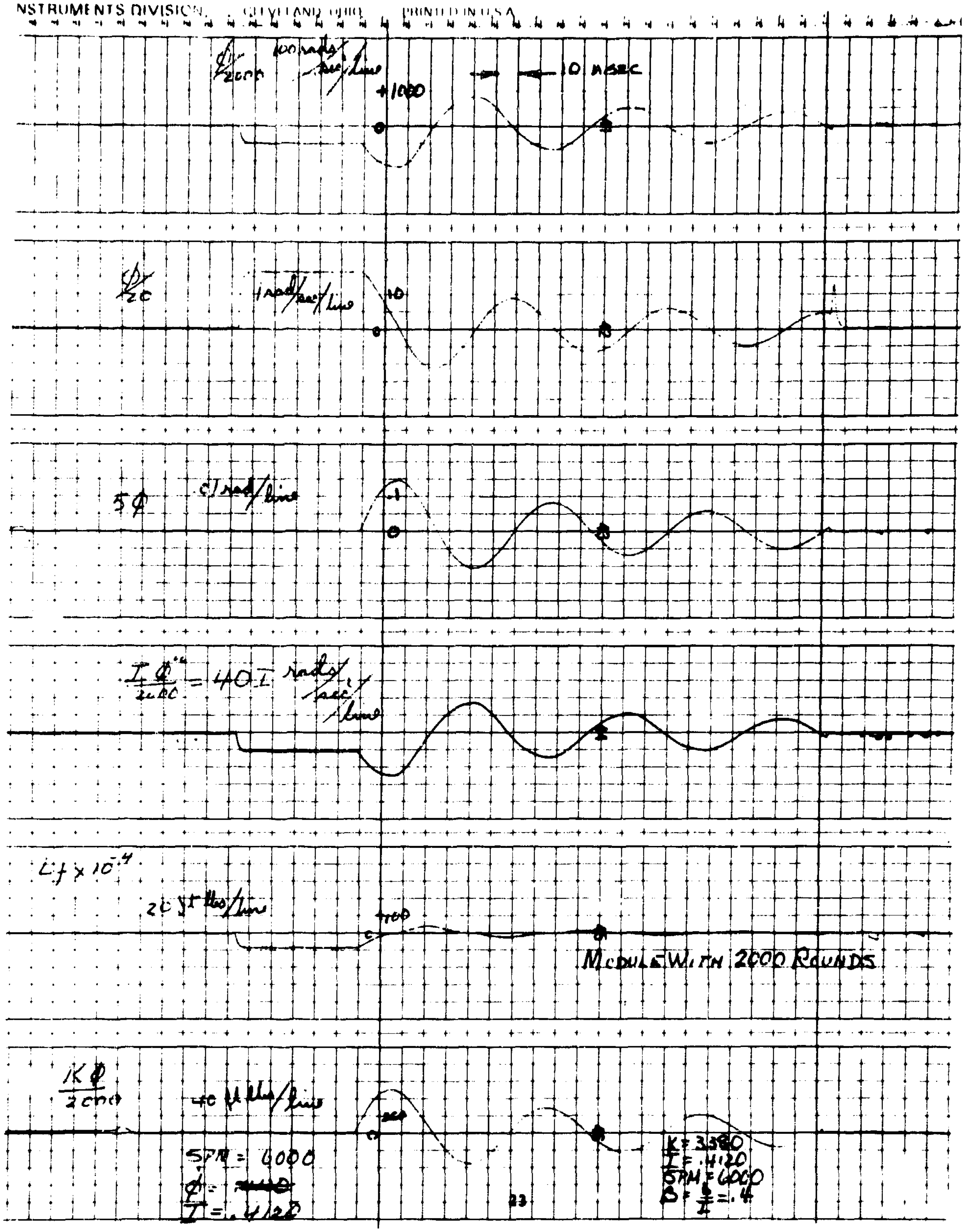


Figure 73. Module with 2000 Rounds

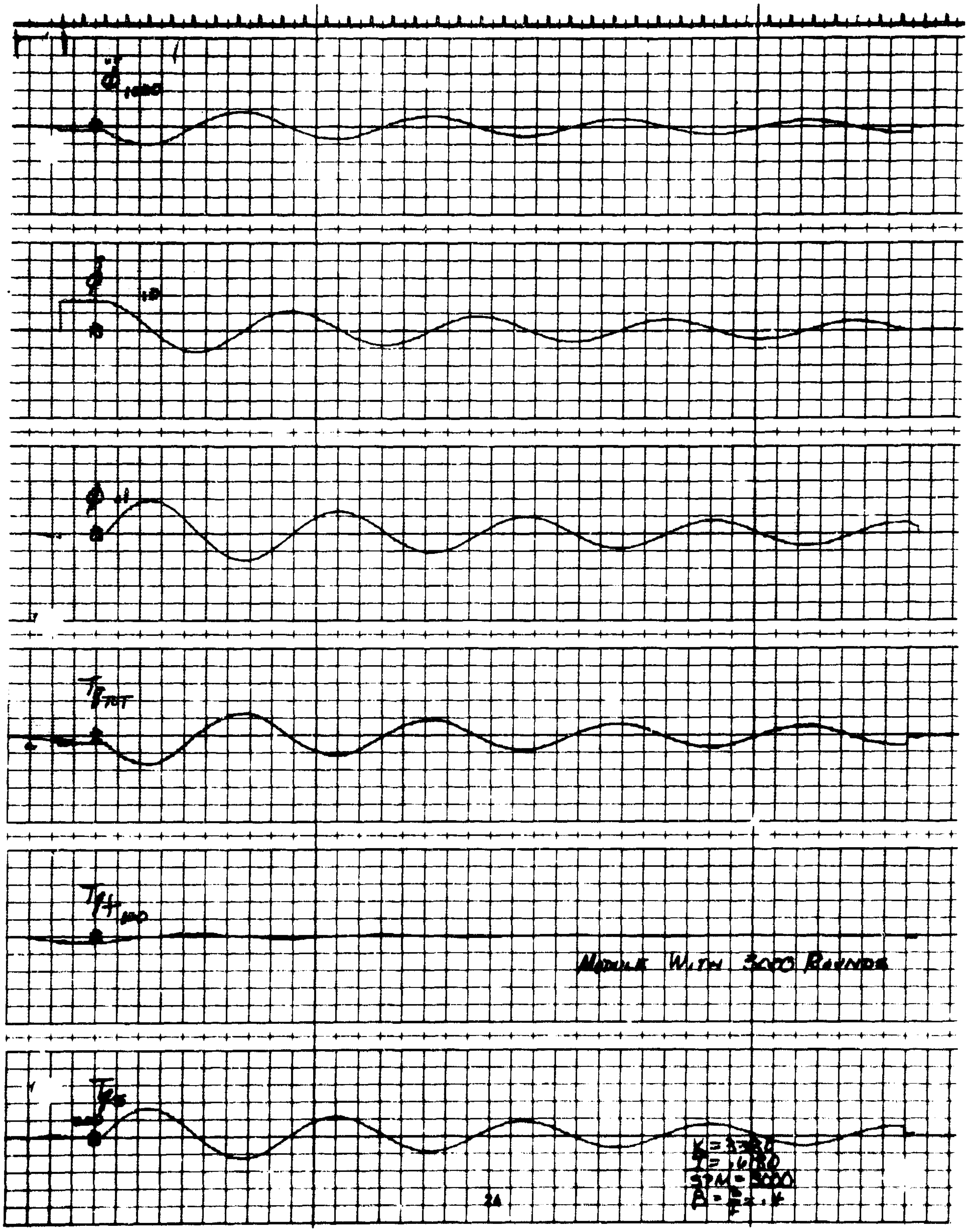


Figure 74. Module with 3000 Rounds

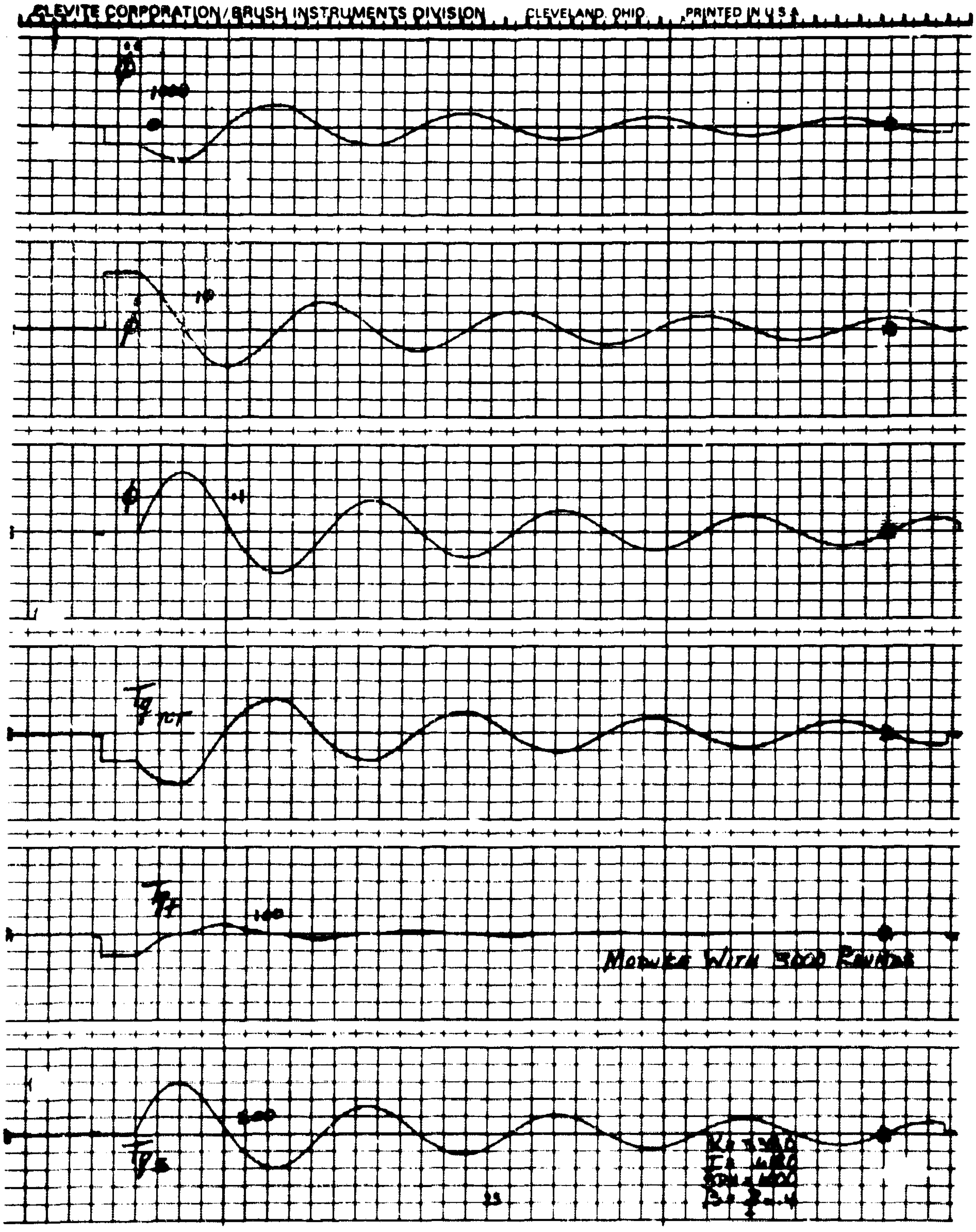


Figure 75. Module with 3000 Rounds

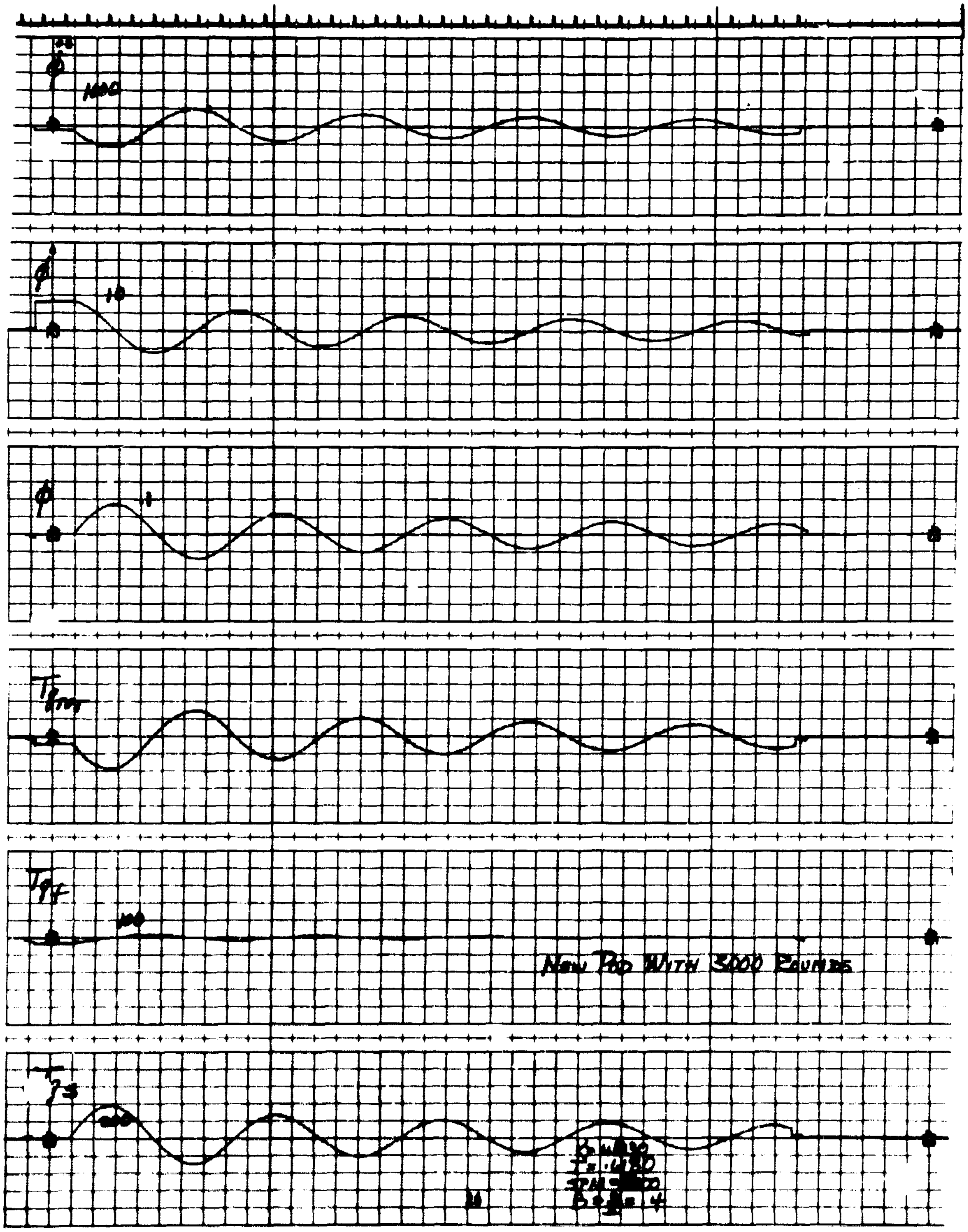


Figure 76. New Pod with 3000 Rounds

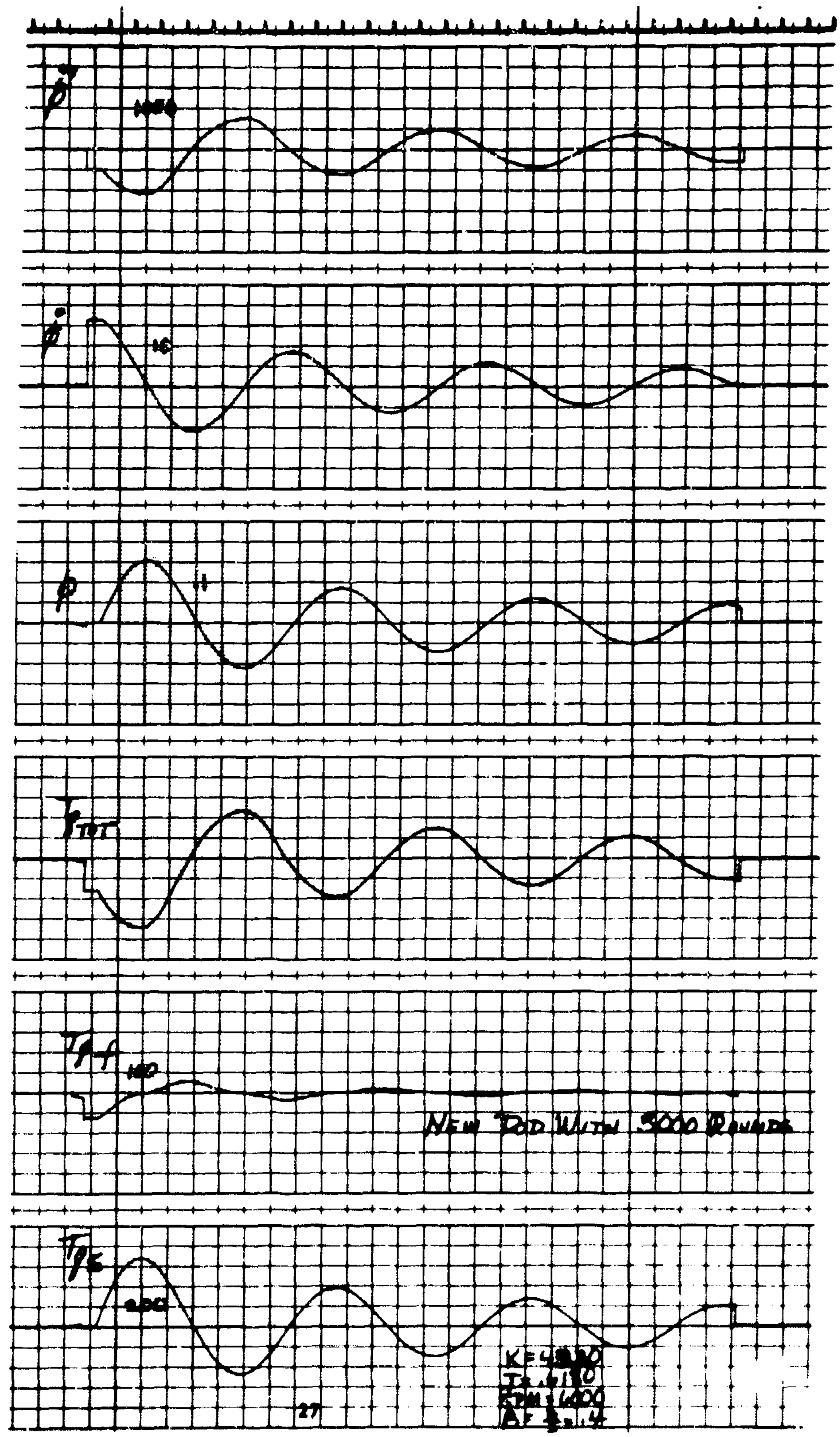


Figure 77. New Pod with 3000 Rounds

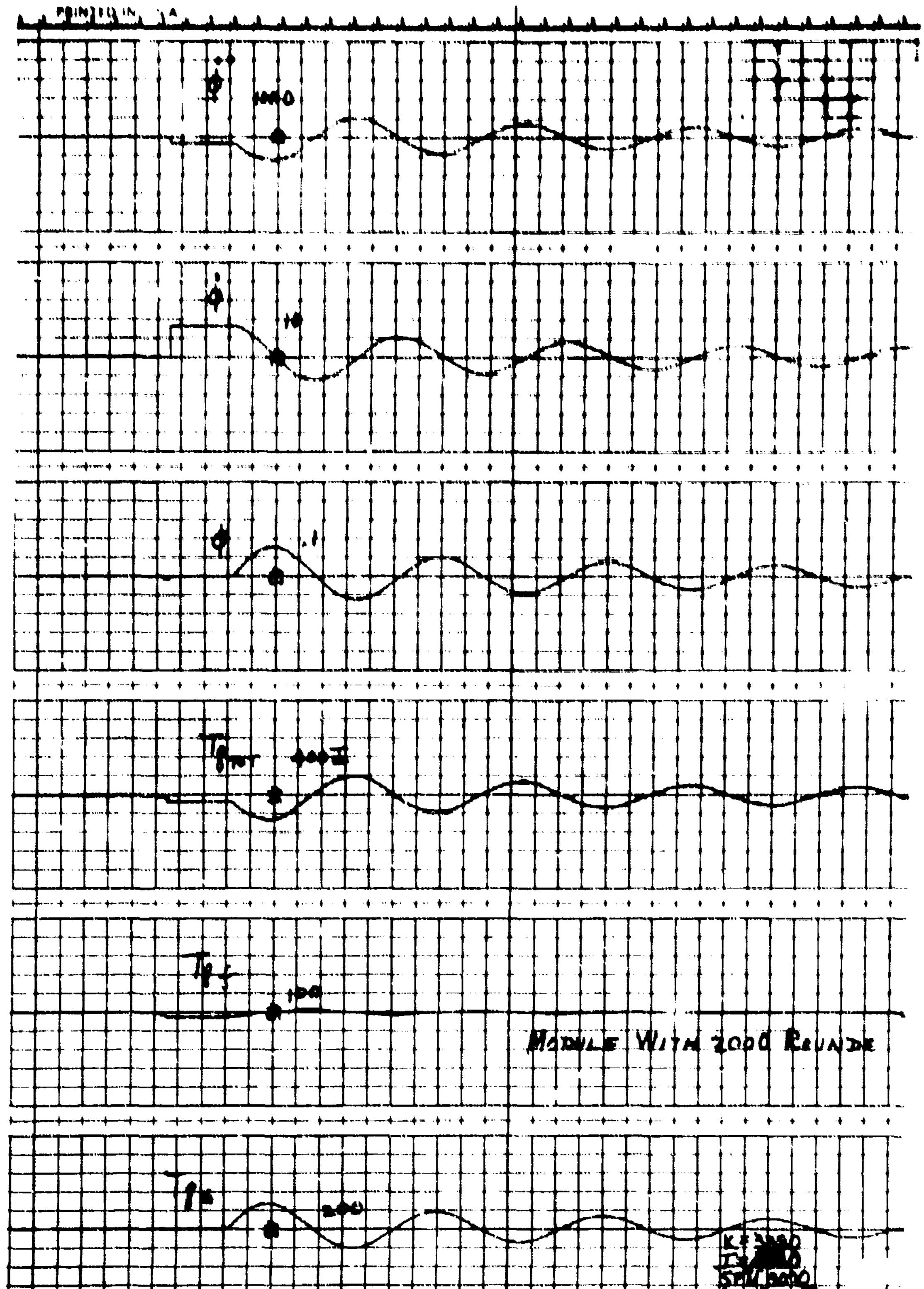


Figure 78. Module with 2000 Rounds

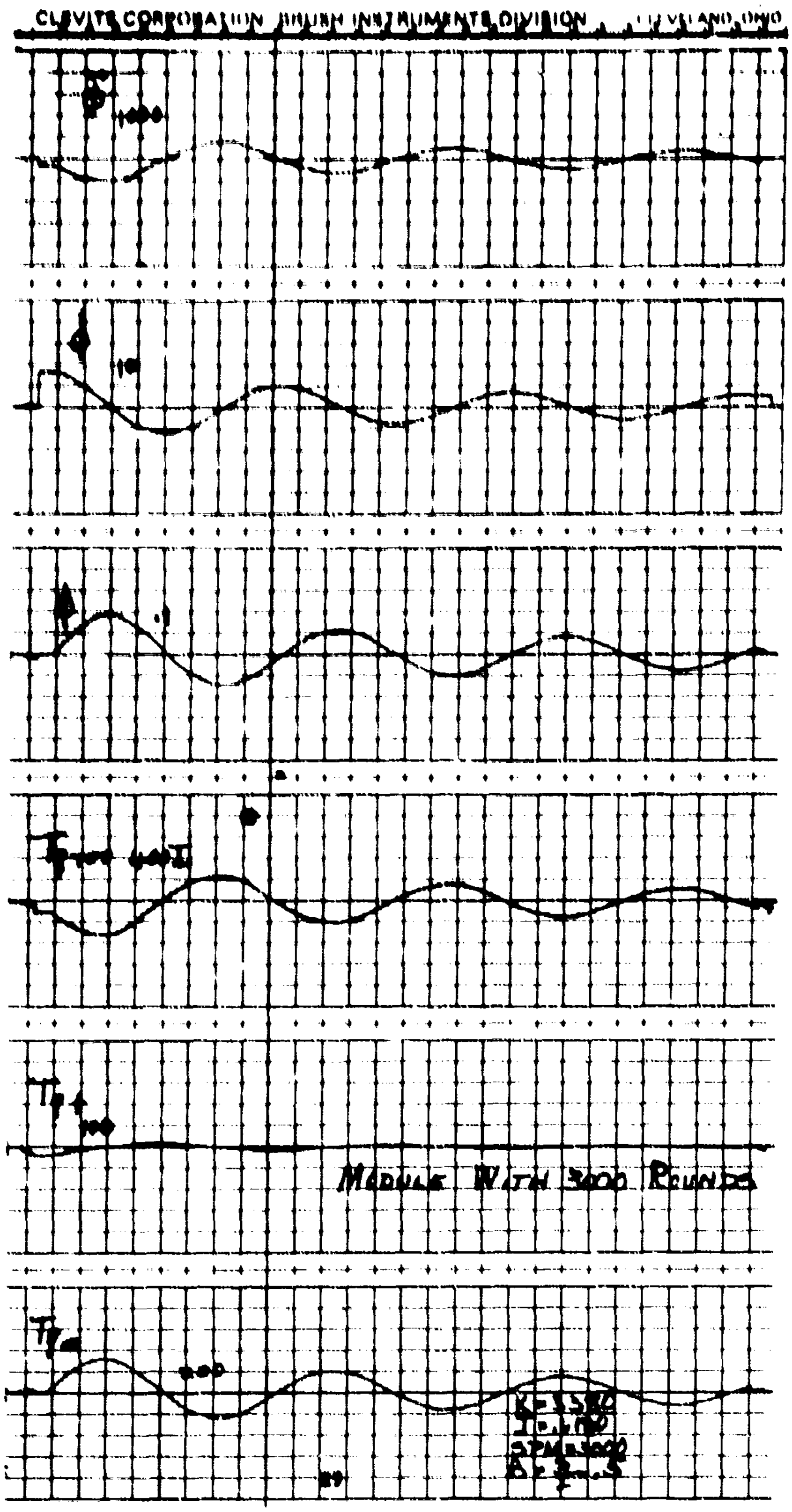


Figure 79. Module with 3000 Rounds

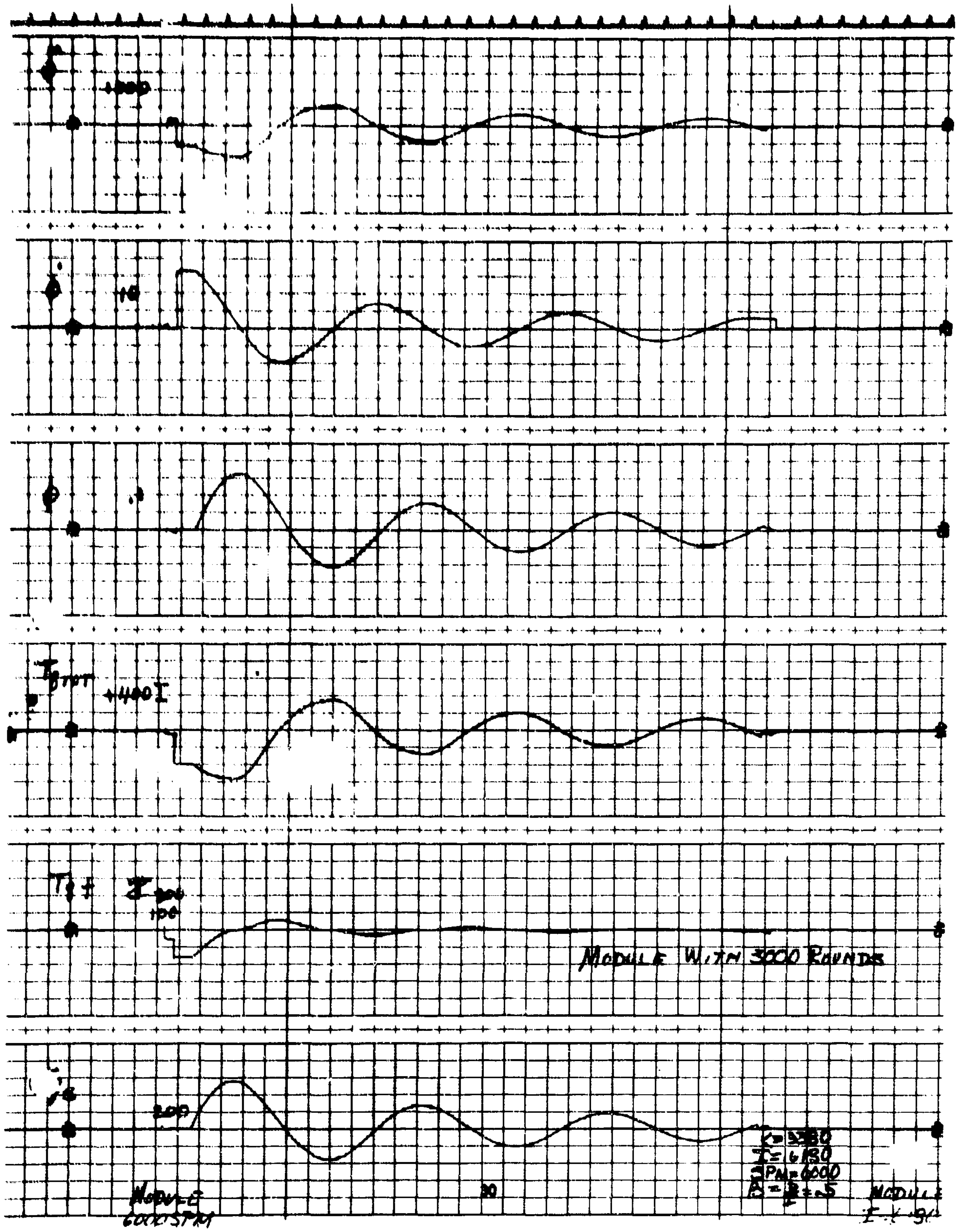


Figure 80. Module with 3000 Rounds

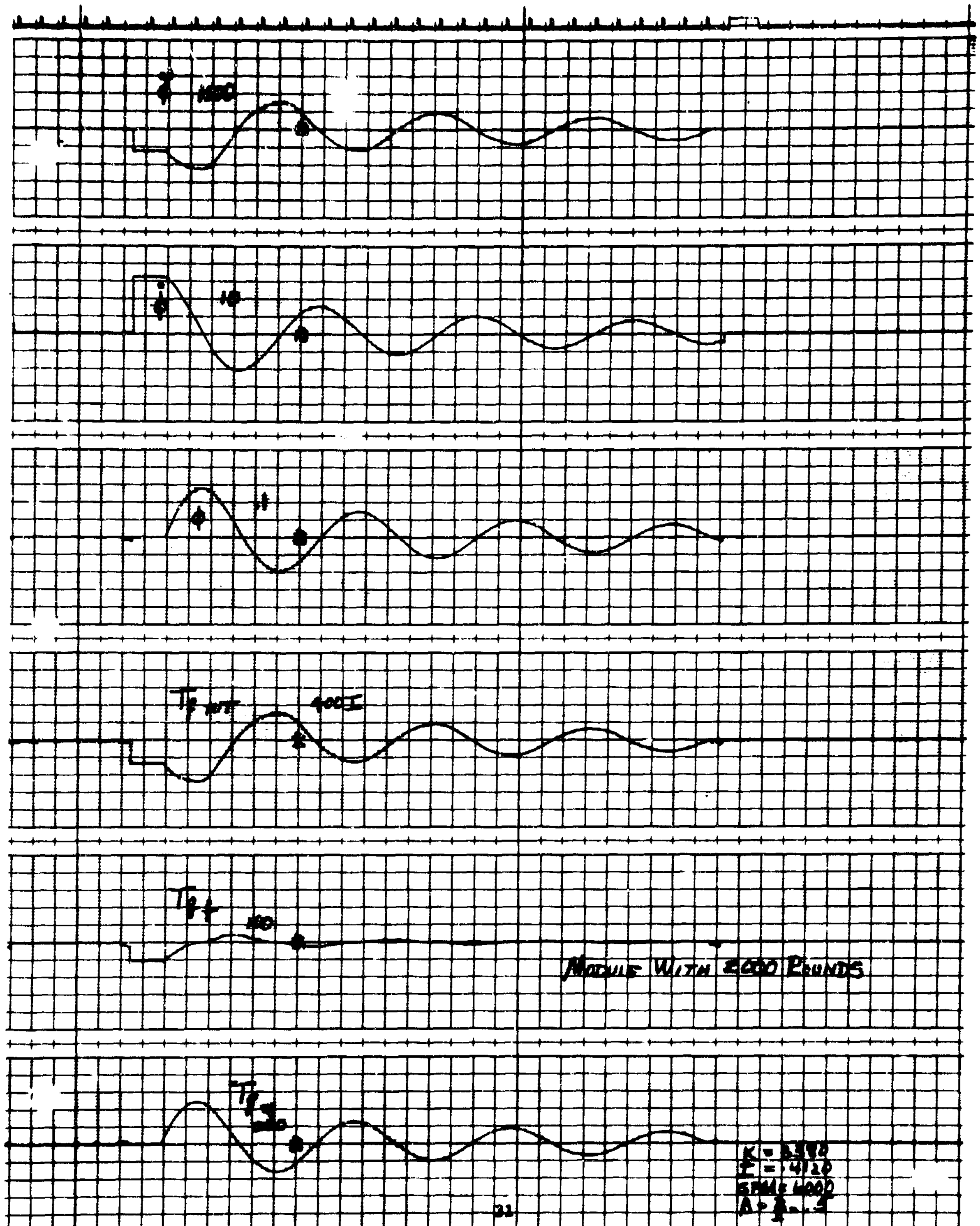


Figure 81. Module with 2000 Rounds

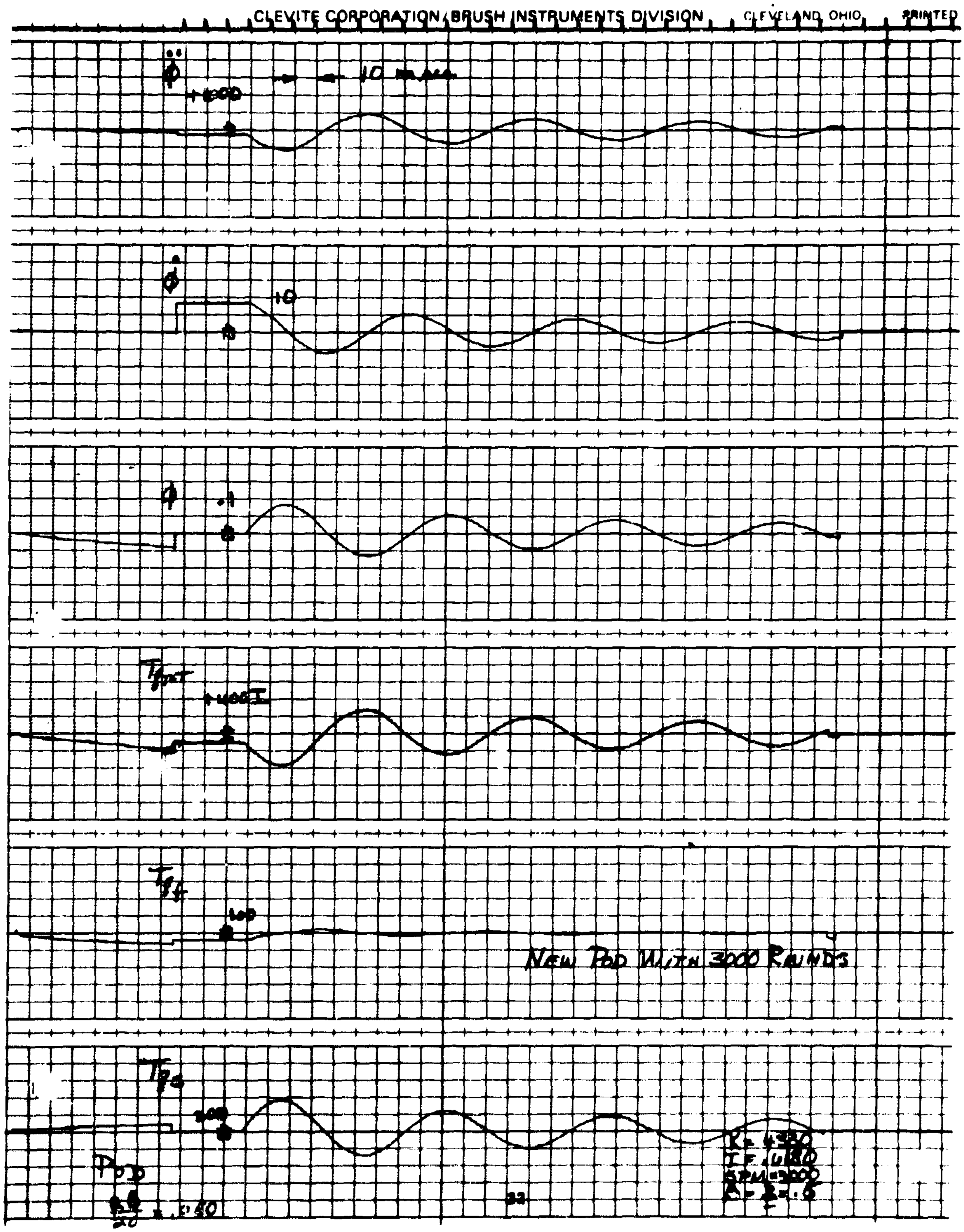


Figure 82. New Pod with 3000 Rounds

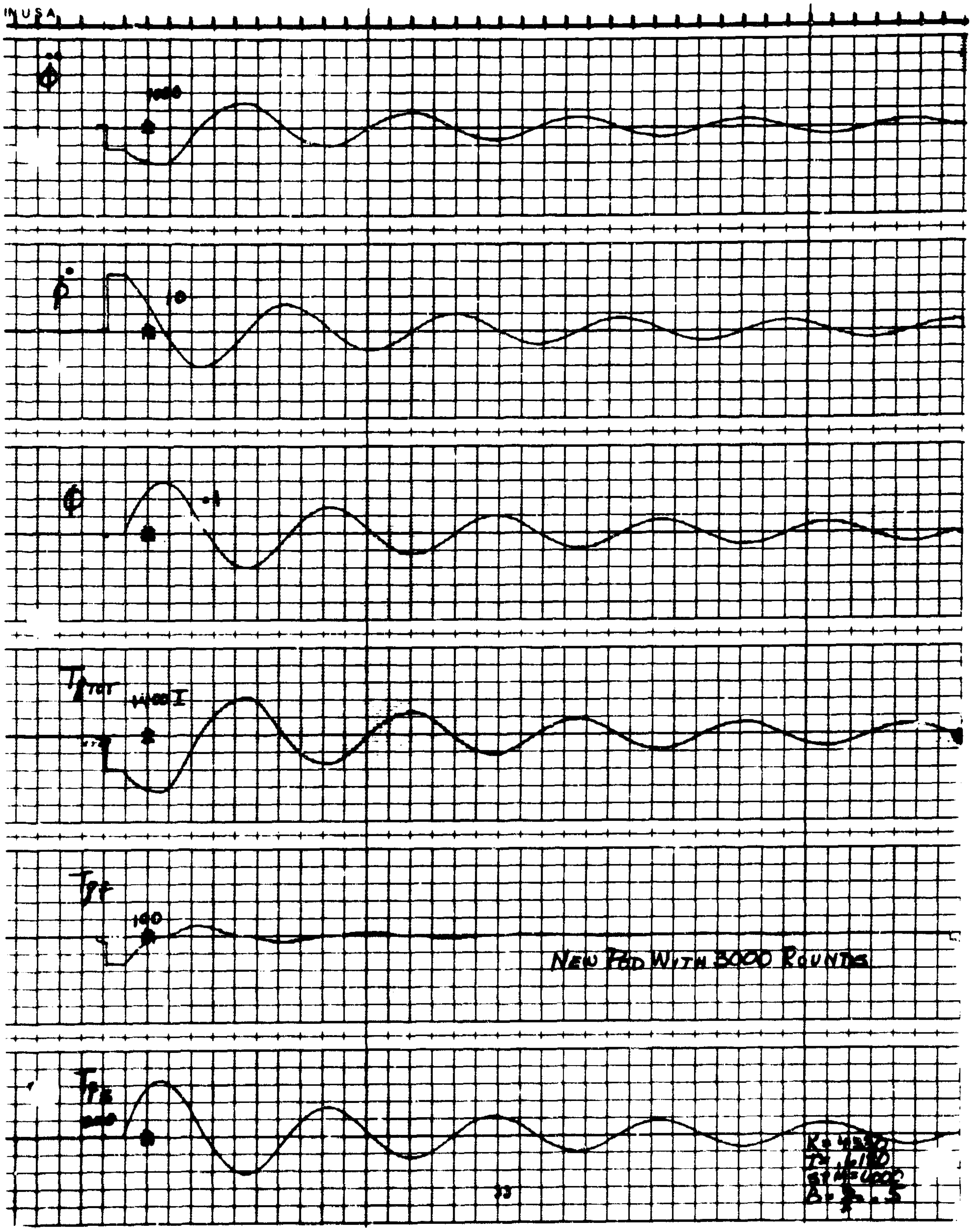


Figure 83. New Pod with 3000 Rounds

SECTION III

SIDE STRIPPING FEEDER, SCOPE ITEM 3

A. INTRODUCTION

The object of this program was to design a feeder that will side strip 7.62-mm linked ammunition belts. These links are designed specifically for end stripping by the inherent reciprocating motion found in most gas-operated rapid-fire machine guns. However, for feeding the minigun the rotary action of the side stripping device is ideal.

The side stripping feeder is designed to replace the end stripping feeder and has many advantages. The new design eliminates many close toleranced, high cost parts. This feeder will cost less and will be easier to maintain. The feeder operation will be less complex; timed clearing will eliminate potential jams. The engineering design objectives were to make the side stripping feeder as simple as possible with reliability equal to or better than the delinking feeder. The side stripping feeder chuting attachment was to be designed with minimal system modification. The XM-28 system was given design priority. While these requirements were closely complied with, four basic external differences from the delinking feeder evolved.

1. The chute attachment is one round length further forward.

2. The links are ejected in the same axial plane and general direction as the spent cartridges.

3. The ammunition enters the feeder with the double loop of link first.

4. The chute attachment location makes it easier to attach chuting in the XM-29 than the present feeder; it is also completely compatible with the XM-21 TAT 102 applications.

The XM-27 system will require modifications due to items 1, 2, and 4 above. The chute path from the ammunition box to the feeder needs to be rerouted. A provision in the cover fairing for the new link ejection location will also be necessary.

In the initial studies three feeder design concepts were generated, two of two shaft design and one of single main shaft design. The chosen design was a two shaft feeder which will be elaborated upon in the history of development portion of this section.

The side stripping feeder hardware which evolved from this design program is shown in Figure 85. Figure 86 shows the feeder mounted to the 7.62-mm minigun.

B. DESIGN OBJECTIVES

The following objectives were established, and the feeder was designed with them as a guide line.

1. Performance - this new stripping concept had to be developed into a working gun feeder and perform as well as conventional end stripping feeders.

2. East of Maintenance - the simplicity of this new design should produce a more easily maintained assembly.

3. Reliability must be a primary consideration.

4. Minimum Size and Weight - design a feeder of minimum size without excess material.

5. Low Cost - the inherent simplicity of the new feeder should result in drastic cost reduction.

C. HISTORY OF DEVELOPMENT

The initial design studies produced a side stripping mechanism that delinks the round and pulls the belt with one sprocket (see Figure 87). The studies also produced three feeder design concepts. Two concepts incorporated a two shaft system. Both two shaft designs are alike in having one shaft support a stripping device and the second support a feeding sprocket. The third concept utilize a single main shaft which supports one sprocket that both strips and feeds the rounds to the gun.

The first two shaft test feeder fabricated was basically a side stripping mechanism attached to a module feeder (66D10013). The basic differences between it and the present end stripping MAU-56 feeder are as follows:

1. The ammunition entrance is relocated 20 degrees counterclockwise, looking forward, and one round length further forward longitudinally along the gun.

2. The ammunition belt feeds a double loop of the link first; in the end stripping feeder the single loop is fed first.

3. The number of parts and the overall length of the feeder have been reduced.

Initial fire testing of design 1 showed that the timing between the stripping and feeding sprocket needed adjustment. Four M-13 NATO links were broken during stripping. This was corrected and testing continued. After the feeder accumulated 12,000 rounds, the following effects were noted.

1. The stripping action of the links severely marked the rounds producing small brass chips. However, the marked cartridges and brass chips did not adversely affect gun operation.

2. Slightly higher torque peaks than the end stripping feeder were experienced during stripping, although the average stripping torque was about the same. The higher torque peaks did not effect gun operation.

3. Rates of 4200 spm were attained without mishap. Above 4500 spm, some links were broken at the base of the double loops while being stripped.

At this point the feeder sprocket handoff to the gun worked fine; the round control was good, but some links were broken in feeder 1.

Design 2 was built and both feeders were further tested to determine which was the more desirable approach. Design 2 is a two shaft feeder. One sprocket both strips links and feeds the gun bolt. The feed to the gun is excellent. The good feeding action is attributed to the location and shape of a six-tooth feeding-stripping sprocket. This sprocket is timed so that it fully seats the round in the bolt extractor lip, then follows the bolt to hold it there until the nose of the round has entered the breech of the barrel. The round handoff is not critical to the slight mistiming between the gun and feeder. The belt pull capability is excellent and greater than the strength of the belt itself.

Both feeders were tested and compared. Design 2 was chosen over the first design tested for the following reasons: (1) the design is much simpler; (2) is lighter and less expensive; (3) performs better; (4) is more reliable; (5) has greater belt pull capacity; and (6) is easier to maintain.

At this point problems still existed with peak torque and link breakage. Modifications to the stripper sprocket and a new support shaft were made to allow more link clearance while stripping the round. The modifications changed the pivot point of the link single loop while the double loop is stripped (see Figure 88 for stripping action diagram). The first modification tried was the support shaft. A broken link jam occurred immediately. In observing this jam it was noticed links were hung up in the link ejection area. It was possible for the links to pivot upon entering the link chute, allowing the single loop to catch on the edge of the round guide. This caused jamming of the links in the link chute, breaking the captured single loop. The possibility of this recurring again was eliminated by removing the round guide protrusion adjacent to the link ejection chute. Rotational control of the link was gained by adding an extension to the link ejection chute (see Figure 89).

A clear jam on complement 4, burst 8, caused another stoppage (see Appendix III-C, Test Results). A round rammed the clearing finger, shearing the clearing stop pin. The feeder was repaired by replacing the spring pins, and testing continued successfully for 20 complements to complement 24 when a broken link caused a jam. Visual inspection of the parts revealed no damage and the cause of the stoppage was not readily apparent. Testing was continued in an attempt to determine the cause of the link breakage which recurred infrequently (see Appendix III-C). After complement 31, burst 4, the feeder was removed and disassembled for a dimensional check of all parts. At this time 42,100 rounds had been fired with the feeder. The investigation revealed the inner round guide was bent and consequently moved the round out of position, causing it to be bound up between the aft support sprocket, inner round guide, and stripper sprocket. The inner round guide was straightened and the feeder was tested further.

During the next complement, number 32, repeated clearing jams occurred due to a bent clearing finger. This was repaired and no further stoppages have occurred. The feeder will continue to be tested for durability and wear.

In addition to the 44,100 rounds fired at the range, 1800 dummy rounds were stripped and fed to the gun. This brings the total accumulated rounds on the feeder to 45,900. As previously agreed, 500 steel cased dummy rounds from Frankford Arsenal were cycled to see what effect the steel cases would have on the feeder. The results were good. The side stripping action of the M-13 link showed no damaging marks on the steel cases and the feeder performed perfectly. Aluminum cases are still not available for test, but no difficulty is expected in the stripping or feeding of these cases.

D. METHOD OF OPERATION

The basic operation of this feeder is the very reliable rolling action of two sprockets. As can be seen by the disassembled feeder (see Figure 90), there are not many parts. Figure 91 shows the ammunition entering the feeder, double loop first. The stripping action starts when the stripper sprocket engages the ammunition belt between the single and double loops of the link. Stripping occurs in sequence with the trailing single loop first and the double loop second. The belt pulling sprockets carry the linked ammunition belt into the sprocket. It supports the round while the single loop is stripped. The single loop uses the belt pulling sprocket shaft as a pivot point while the double loop is stripped from the round (see Figure 88). The stripper sprocket is also the feed sprocket and carries the round with the aid of a guide to the gun bolt. Figure 92 shows this area of the feeder. Clearing gates are controlled, as in the MXU-470 module, by timing the finger's movement through the round path, thus eliminating clearing jams. This feeder is mounted to the gun in the same way as the delinking feeder. The timing device is an improved wide spring, more easily used than the pin used in the delinking feeder. Figure 93 shows the feeder mounted to the gun.

A P P E N D I X   III-A

Drawing

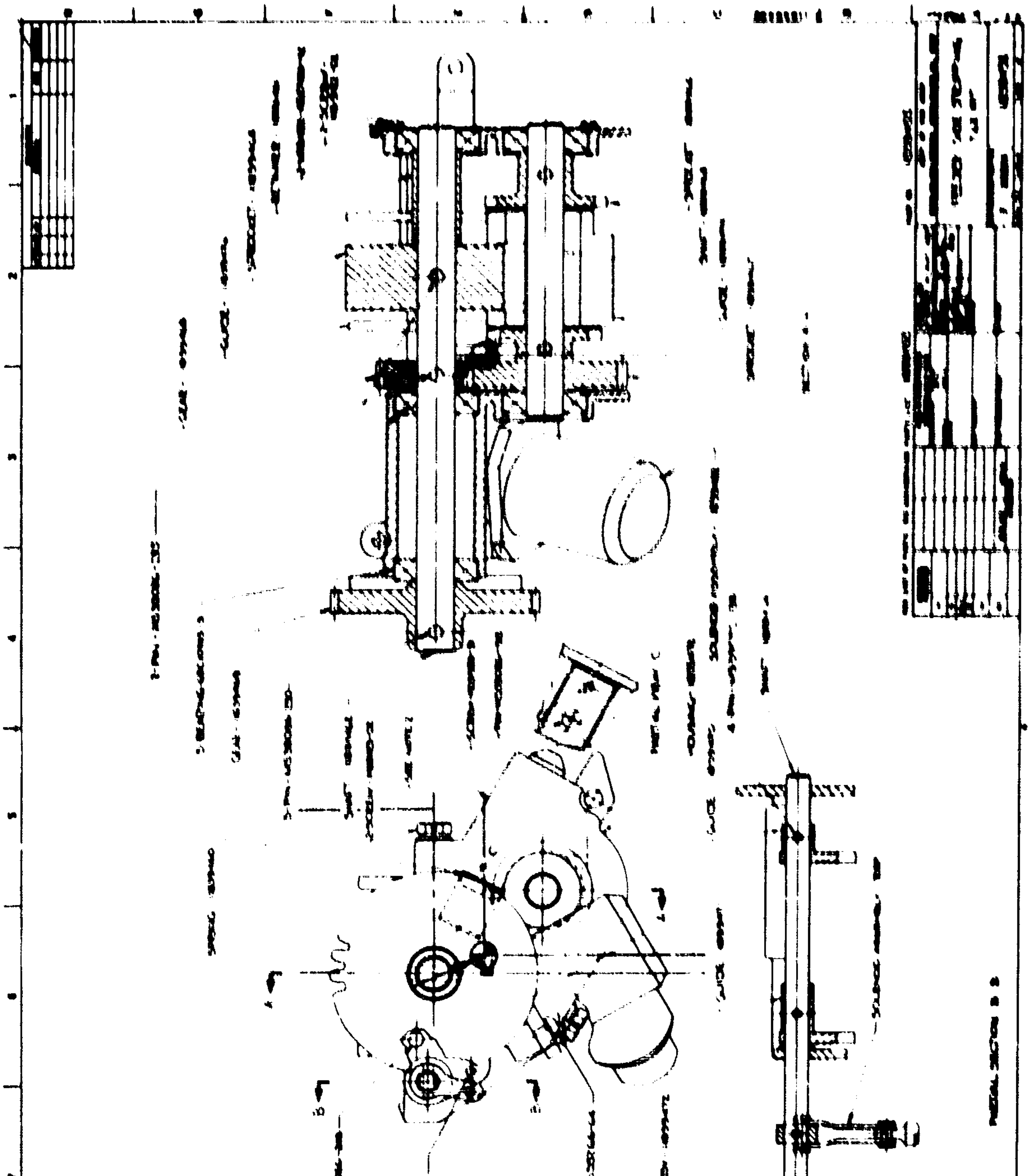


Figure 84. Side Stripping Feeder

APPENDIX III-B

Photos and Illustrations

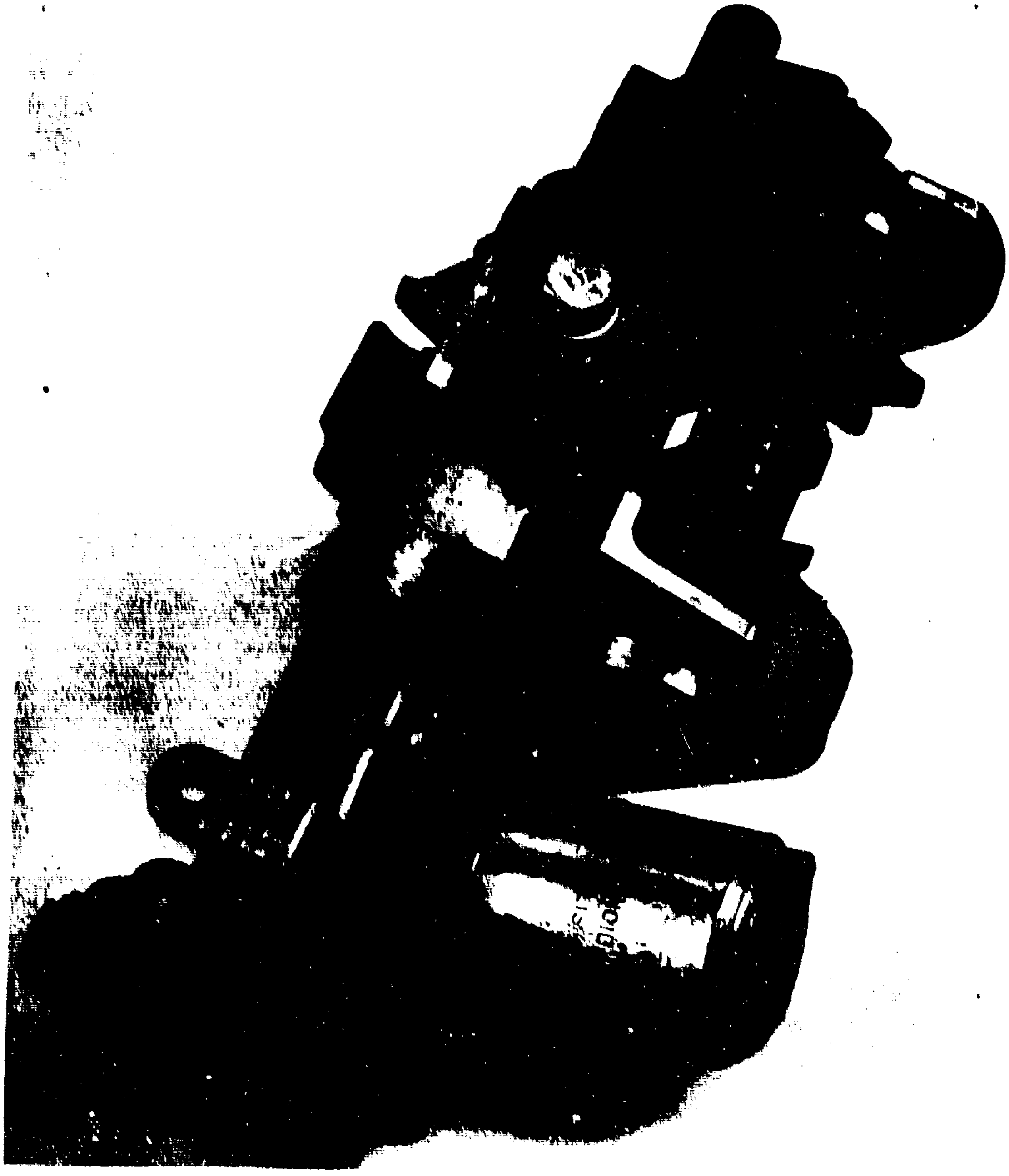


Figure 85. Feeder

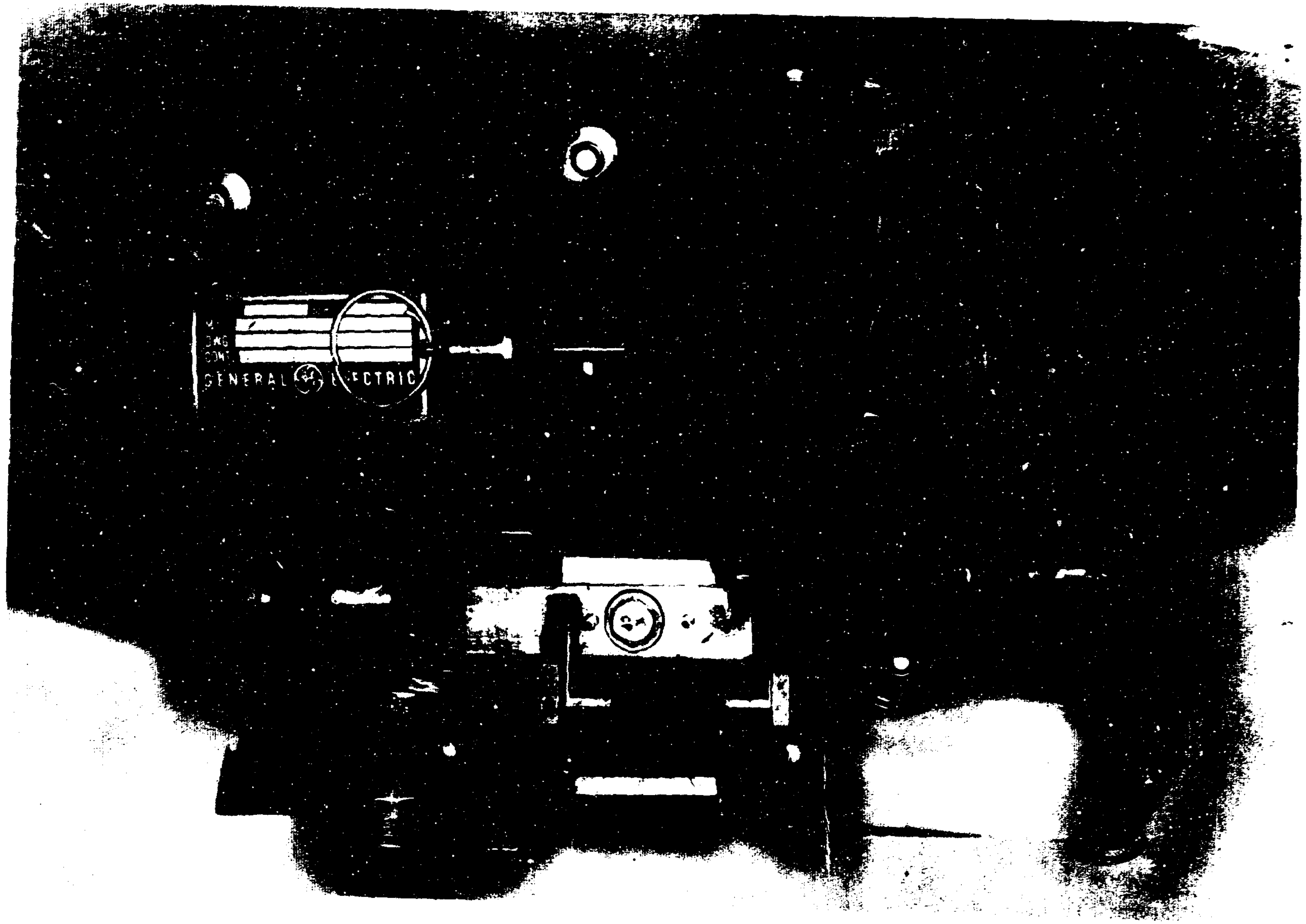


Figure 86. Feeder and Gun

Figure 87. Side Stripping Mechanism

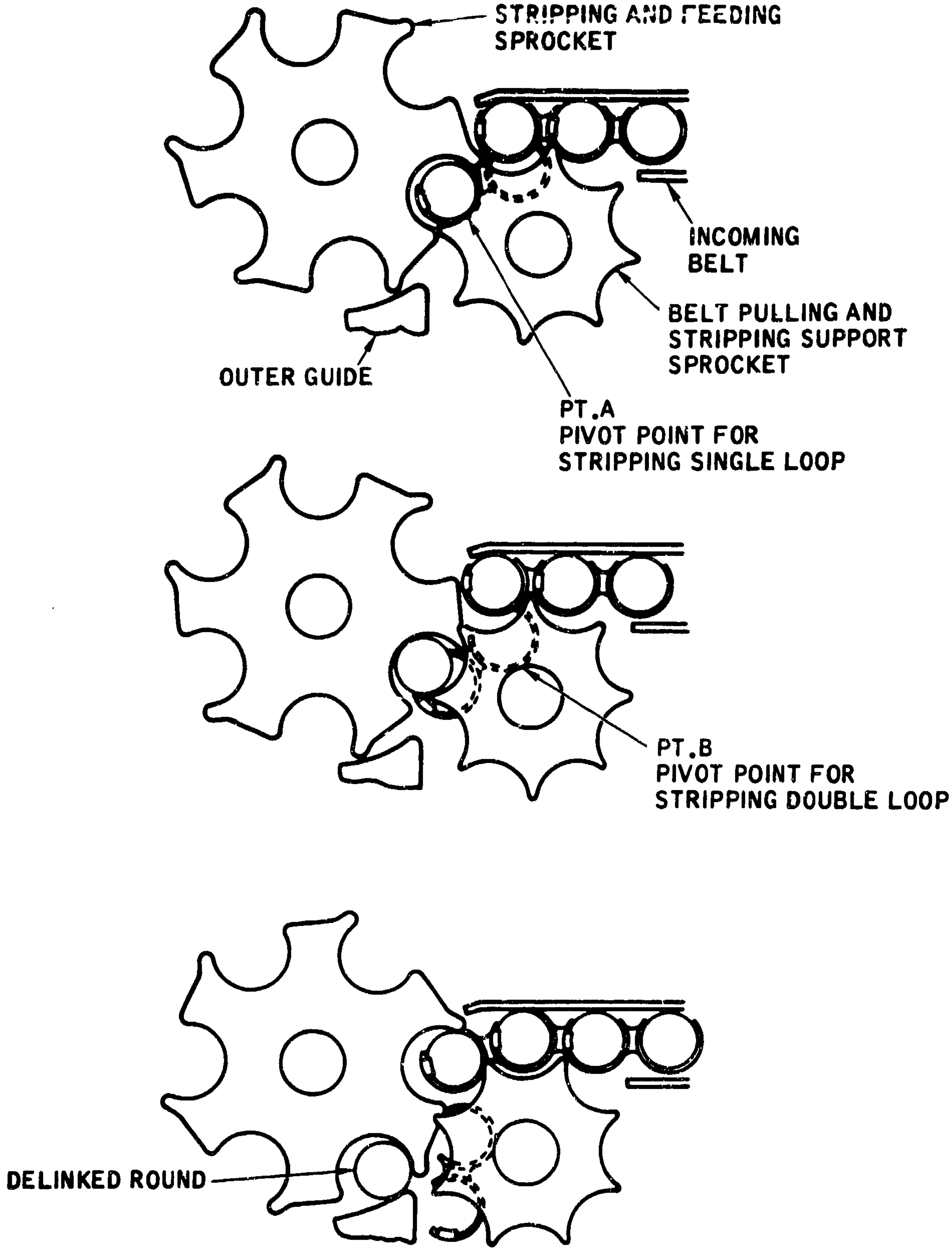


Figure 88. Side Stripping Diagram

NOTE: ADDED EXTENSION AND REMOVAL OF MATERIAL PREVENTS LINK FROM PIVOTING AND HANGING UP ON INTERIOR OF OUTER GUIDE

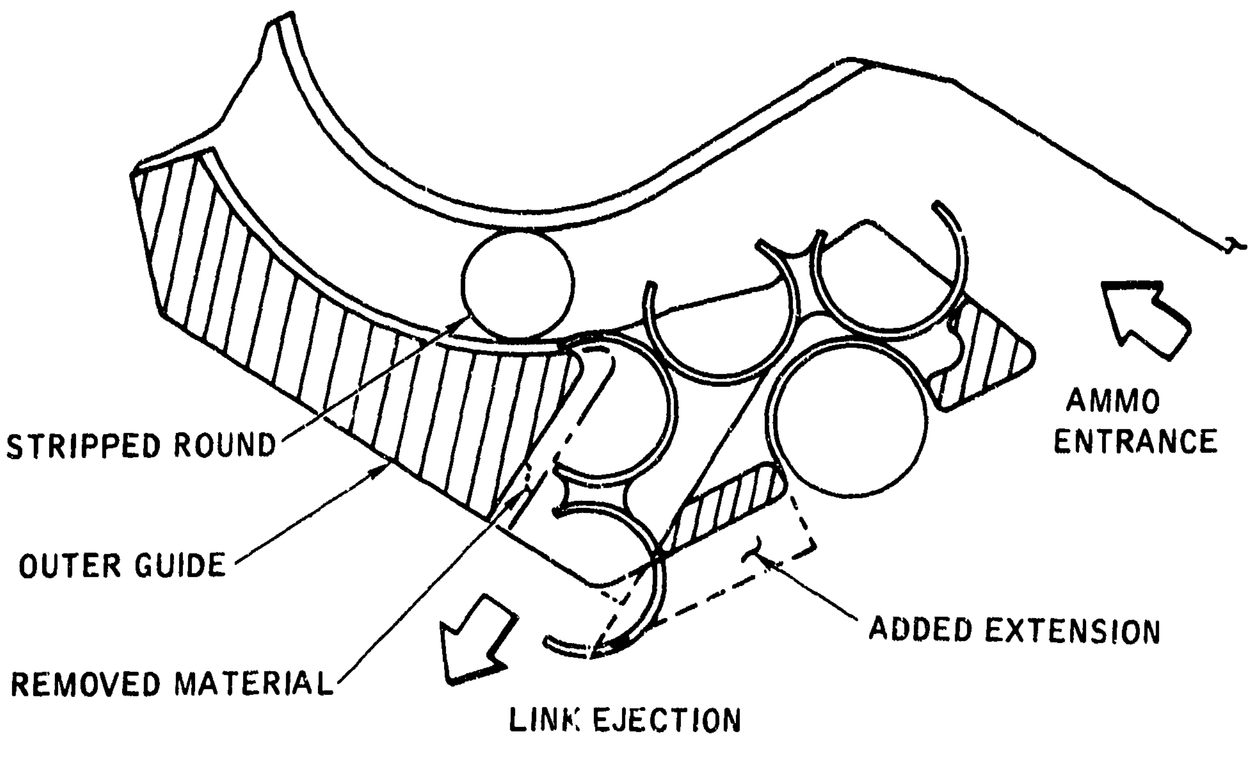


Figure 8[illegible]. Link Jam

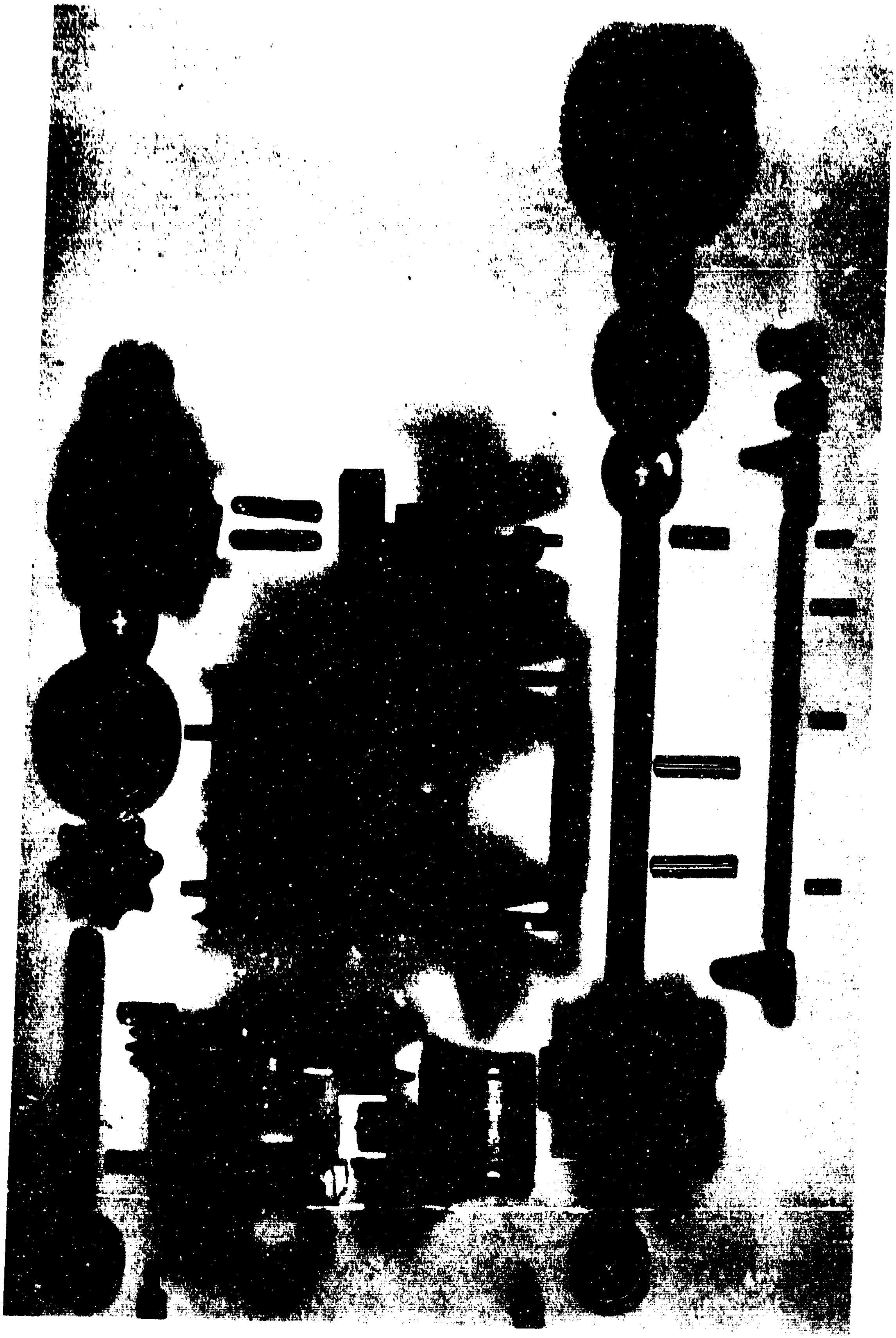


Figure 90. Disassembled Feeder

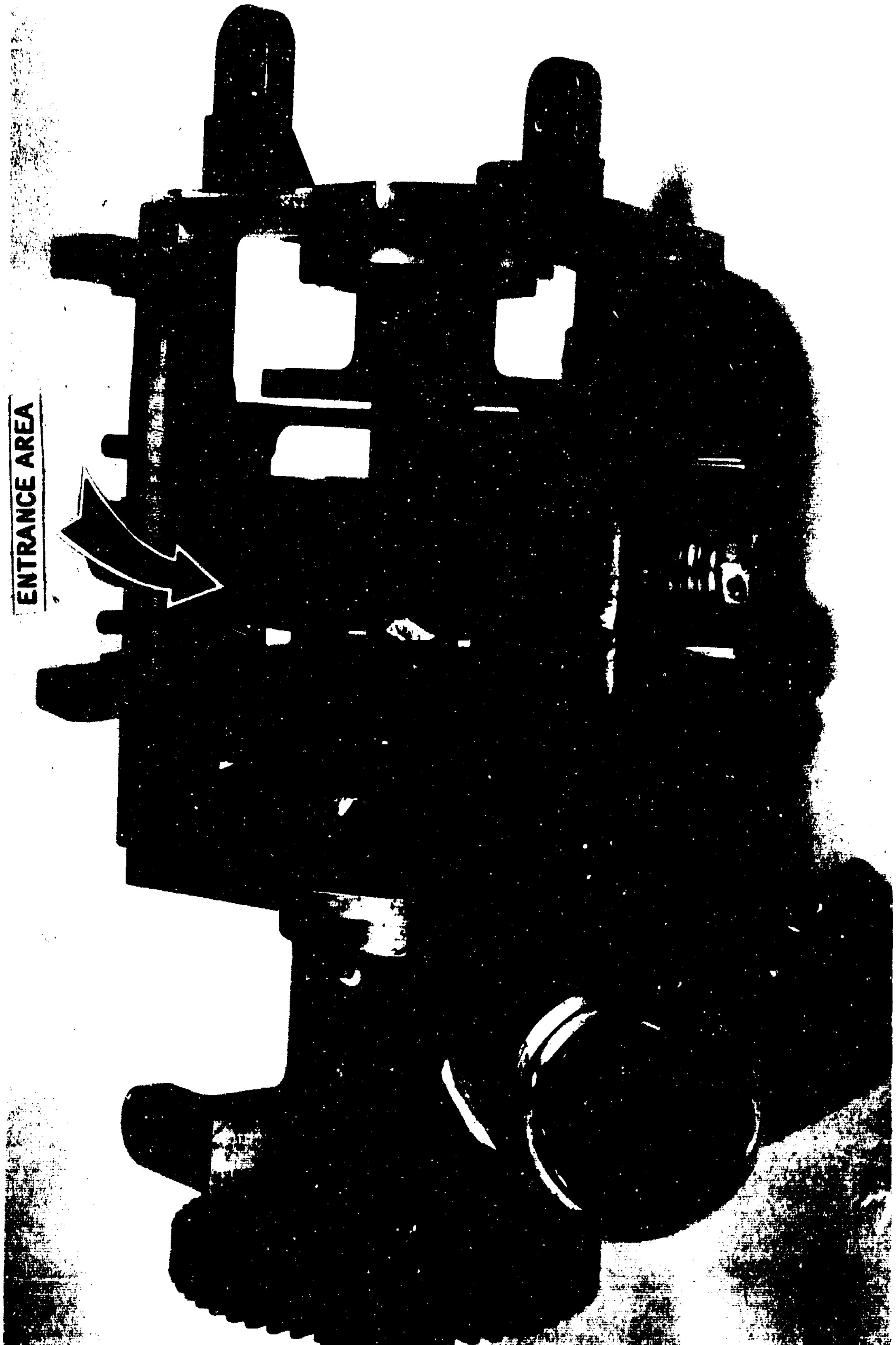


Figure 91. Entrance Area

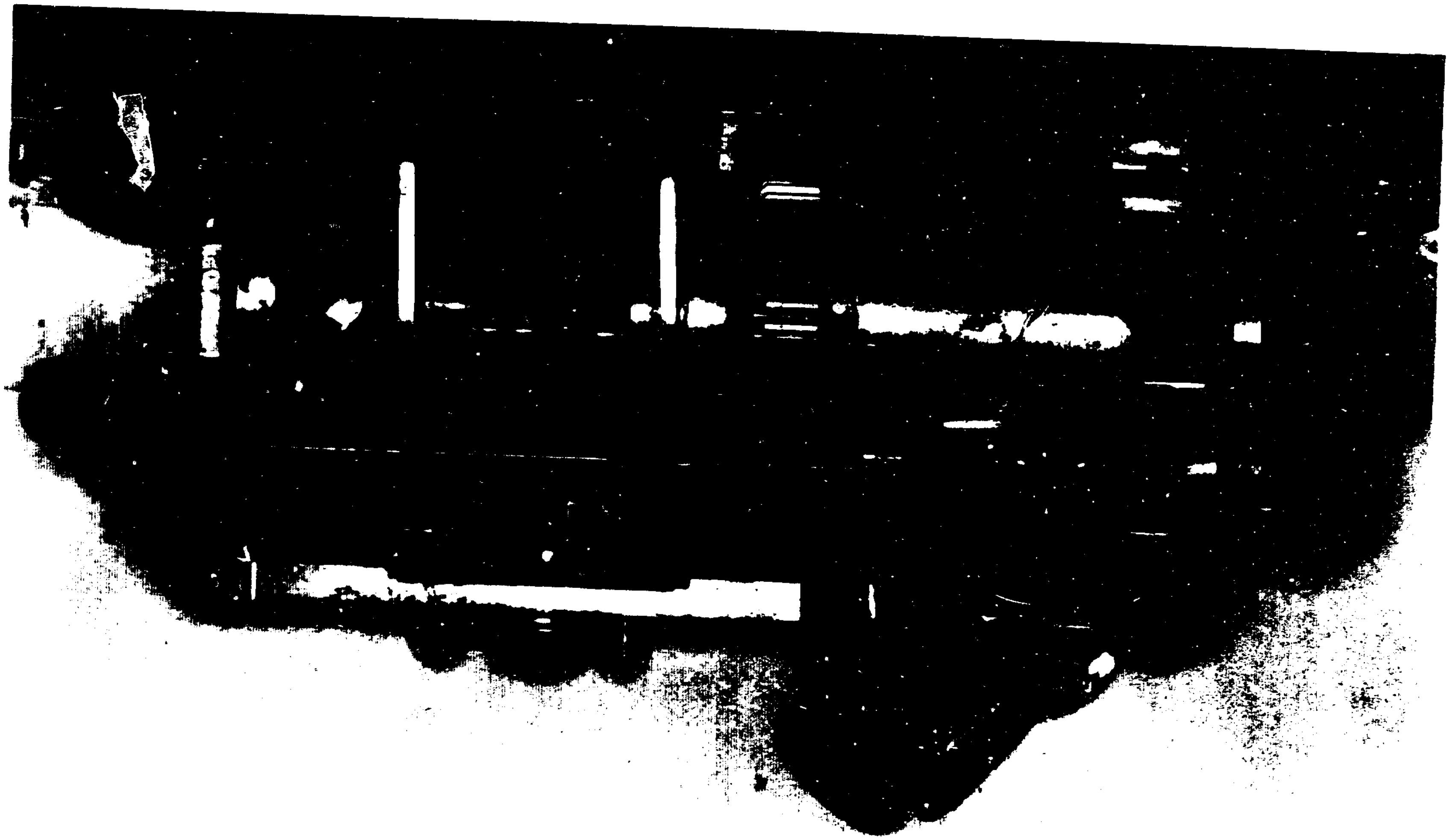


Figure 92. Feed Side

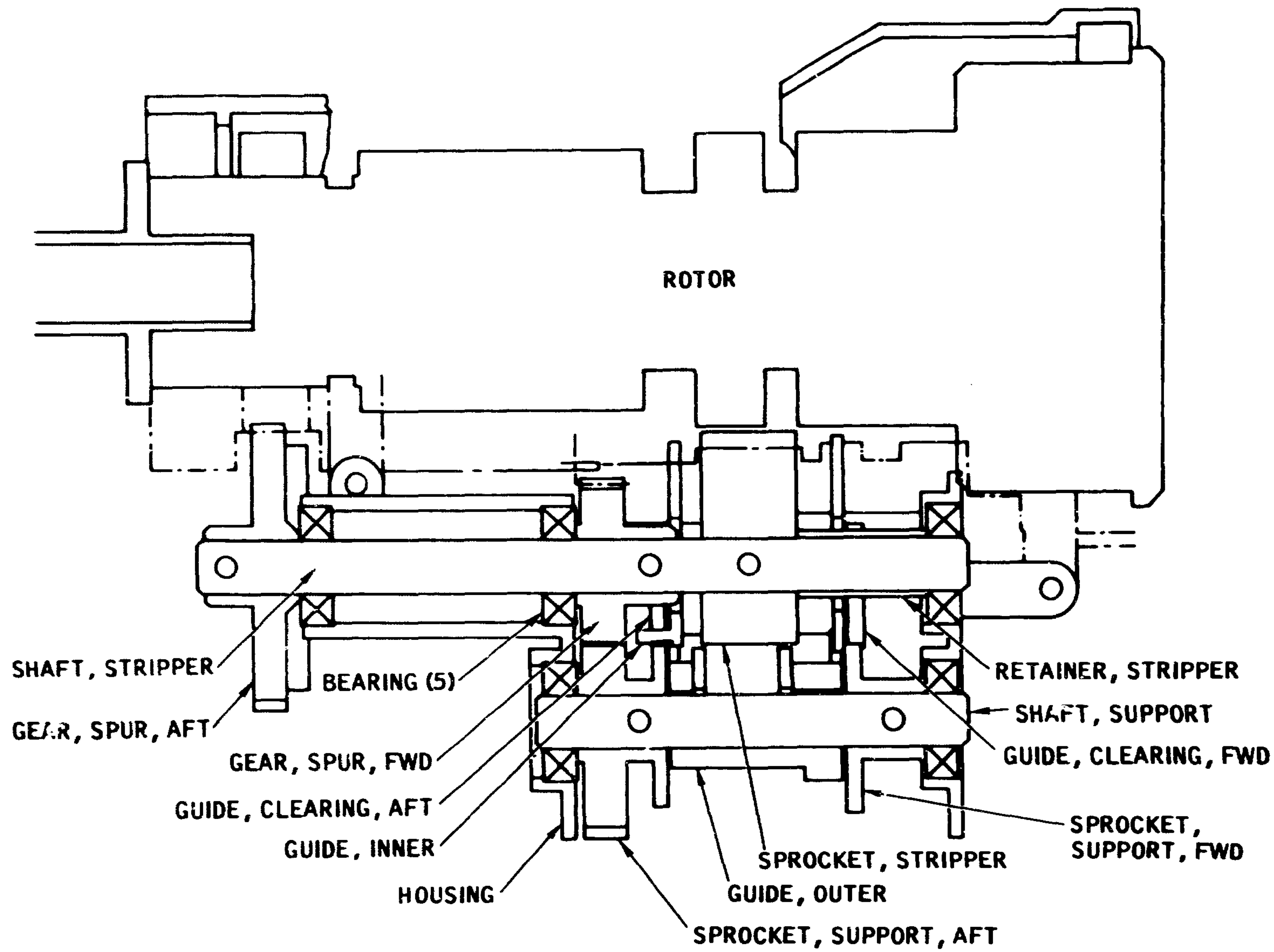


Figure 93. Assembly of Feeder Mounted to Gun

APPENDIX III-C

Test Results

Table XI. Side Stripping Feeder, Live Test Results, Design No. [illegible]

Complement Number	Number of Rounds	Rate (spm)	Remarks
1	2000	6000-[illegible]	OK
2	2000	[illegible]900-6100	200-rd Bursts - OK
3	2000	2000-3900	200-rd Bursts - OK
4	1600	6000	200-rd Bursts - clearing jam burst 4 - sheared pin, bent tins
5	2000	6000-6600	OK
6	2000	5800-6000	Clutch installed - aft gear pin set slightly - pin changed
7	2000	5800-6000	200-rd Bursts - OK
8	2000	5800-6000	200-rd Bursts - OK
9	1200	2850-2900	Removed feeder - no malfunction
12	1500	5500	OK
13	1500	5200-5400	Aft gear pin sheared after fire out
14	1500	5200-5400	200-rd Bursts - OK
15	1500	5200-5400	200-rd Burst - OK
16	1500	5400-5500	Gun jam - mistimed cleared - long burst to fire out 300 rds
17	1500	5500	OK
18	1500	2700-2800	OK
19	1500	1500	OK
20	1500	700-1100	Long burst to fire out 400 rds
21	1500	700-800	200-rd Burst - OK
22	1500	1300-1400	OK
23	1500	1400	OK

Table XI Side Stripping Feeder, Live Test Results, Design No. 2 (cont.)

Complement Number	Number of Rounds	Rate (spm)	Remarks
24	1500	1500	Jam – burst 4 – broken link
25	1500	1800	Gun jam – feeder OK
26	1500	1100-1300	Mistimed
[illegible]	1500	1100-1200	OK
28	1500	1000-1100	Jam with approximately 10 rds left - mislinked rd - feeder OK
29	1500	1100-1200	150-rd Bursts – OK
30	1500	1100-1200	Jam - broken link
31	1500	1100-1200	Jam - bursts 3 and 4 - broken links - feeder removed for investigation - bent inner round guide found - all pins replaced, guide straightened
32	2000	6000	Repeated clearing jams - feeder removed - set pins along clearing shaft found - bent clearing finger repaired, pin replaced and fired out - OK
	1800		Dummy rounds - OK

APPENDIX III-D

Weight and Center of Gravity

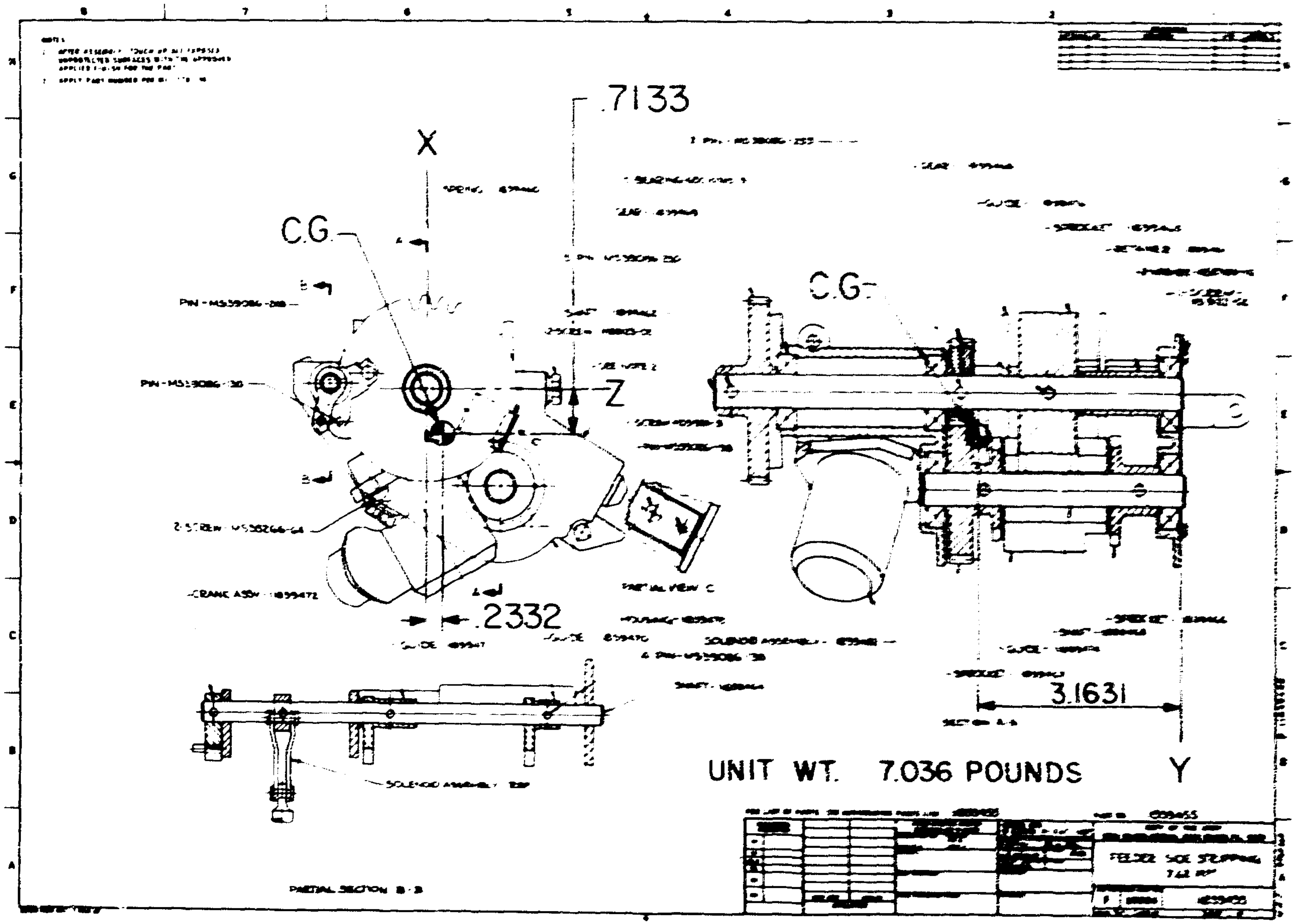


Figure 94. Side Stripping Feeder

SECTION IV

MINIGUN GUIDE BAR, SCOPE ITEM 4

A. INTRODUCTION

The research and development work on the guide bar has been completed. The work has shown no further improvements can be made without changing the highly desirable characteristics of the present one-piece bar. The present design is best for the existing gun and feeders.

The purpose of this work was to design a new guide bar that would increase the gun's degree of tolerance to feeder timing and damaged ammunition. The approach taken was that of determining the status of the present guide bar's interfacing with the gun and feeder through the use of tolerance studies and high-speed films. With this known, a basis could be established for further improvement.

B. CONCLUSIONS AND RECOMMENDATIONS

1. The tolerance studies and high-speed films show that the present system is the most desirable design for the existing gun and feeder systems.

2. The ...ent to which the guide bar can compensate for late feed is limited. To further decrease the dependency of round control on feeder timing during handoff, some other mechanism(s) must be added to the guide bar or feeder.

3. The amount of damage to guide bars due to late feeding and damaged ammunition is small and does not justify any further engineering effort on this part; therefore the research and development work on the guide bar has been terminated.

4. Interference exists between the round and the guide bar rim guide during the transition of the round from the feeder to the guide bar. The tolerance limit on the dimension that controls the feeder rim guide location should be tightened for both the pod and delinking feeders to correct this condition.

C. TOLERANCE STUDIES

The tolerance studies were undertaken to determine the possibility of having a late feed situation and damaged ammunition with the present design tolerance on the guide bar, gun, and feeders. A large share of the values used in these studies was obtained from a 10 to 1 layout. The actual analysis, including all of the factors considered in determining results, is found in Appendix IV-B. The following is a summary of these results.

1. In every feeding system, the desired amount of crush-up exists between the bolt head, round, and guide bar (see Appendix IV-B, pages 198 and 199). Every system feeds the round into the gun early. It is impossible to have a late feeding situation due to the accumulation of tolerances.

2. Marginal interference exists between the round and the guide bar rim guide for the pod and delinking feeders during the transition from feeder to guide bar (see Appendix IV-B, pages 224 through 227).

3. Clearance always exists between the bolt head keyway and the guide bar key, and between the bolt and the guide bar (see Appendix IV-B, page 202).

4. The rim guide always controls the round so that it is always free to enter the bolt head extractor lip (see Appendix IV-B, page 203).

5. Either clearance or a line-to-line condition was found to exist at all times between the rim guide flat and the feeder housings (see Appendix IV-B, page 240).

D. HIGH-SPEED FILMS

In order to thoroughly understand the actual dynamic conditions of round handoff to the bolt for all feeding systems, high-speed films were taken of the round cycling at high rate. The summary of results for the films is in Appendix IV-B, Table XII, page 246

The filming was accomplished by removing the barrels from the rotor, inserting plexiglas plugs (see Figure 108) into the rotor's barrel holes, and cycling dummy rounds through the gun while simultaneously taking high-speed films through the plexiglas plugs.

These films show that all systems feed the round into the gun early. The module, pod, and A-37 feeder sprockets push the round against the guide bar at all times. The effect of this is seen in the deflection of the guide bar fingers. On the other hand, the delinking feeder presses the round against the inner feeder guides and then causes the round to bounce several times against the fingers before it is fully seated in the head bolt. The films have shown that the feeders move the round into the gun very efficiently.

F. EVALUATION OF VARIOUS GUIDE BAR DESIGNS

The areas of the guide bar that are susceptible to damage are the fingers and the rim guides. The fingers may be damaged when a bolt assembly has a sheared roller stud. A broken rim guide occurs when a round is pushed against it by the bolt head - as in a late feed.

The average hangfire and late feed occurrences were 1 in 1,000,000 and 1 in 100,000, respectively, based on General Electric's SEA malfunction reports from January 1968 to March 1969. Approximately 25 percent of the hangfires cause bent fingers, and a very small percentage of the late feeds cause broken rim guides.

Even though these statistics indicate a very high reliability for the present guide bar, ideas for decreasing the cost and/or increasing the already high reliability of the present guide bar were accumulated and evaluated. The following ideas for possible guide bar and round control improvement are discussed below.

1. Replaceable guide bar fingers
2. Modified round path
3. New rim guide
4. Mechanisms to increase the gun's tolerance for late feeding
   a. Movable rim guides
   b. Accelerators

1. Replaceable Guide Bar Fingers

It was thought that replaceable guide bar fingers would help to save the guide bar when a bolt body roller stud shears because of a hangfire. The entire guide bar would not have to be disposed of if bent fingers could be replaced.

This idea has been found impractical because of the infrequency of damage to guide bar fingers, the additional machining required for new fingers, the added cost of casting fingers, and the uncertainty in the capability of designing new fingers with the same strength as the present guide bar fingers.

2. Modified Round Path

During the initial guide bar studies, it was felt that removing material from the guide bar fingers, as shown in Figure 96, would increase the degree of tolerance to late feed. Such a modification would allow the feeder sprocket to be set ahead, consequently increasing the zone in which the sprocket can be retarded.

This approach cannot be used because the sprocket is already advanced as far as it can be - the feeder sprockets press the round against the rotor's stationary tracks in the present design.

3. New Rim Guide

Changing the present guide bar rim guide to the other side of the guide bar (see Figure 97) would reduce manufacturing costs. However, investigation has shown this idea is infeasible. It was found that the minigun's removable track ways would prevent the proposed rim guide from extending far enough to the bolt head extractor lip to ensure full control of the round as it passes from the rim guide to the lip. The guide bar would lose control of the round before it was fully seated inside the extractor lip and, consequently, a double feed situation could occur.

4. Mechanisms to Increase the Gun's Tolerance to Late Feeding

The extent to which the guide bar can compensate for late feeding is limited. Some other type of mechanism must be added to the guide bar or the feeder to further increase the gun's tolerance to feeder timing. Two possible approaches involve having the guide bar rim guide and the feeder inner guides move out of the round's way and having a mechanism push the round ahead of the sprocket. Ideas employing these approaches are as follows

a. Movable rim guides

(1) Rotational displacement rim guides

(2) Translational displacement rim guides

b. Accelerators

(1) Angle-multiplying mechanism

(2) Spring lever mechanism

(3) Feedback system with actuated solenoid (solenoid kicker)

Since only a very small number of guide bars are damaged because of late feeding, it would be impractical to pursue any design employing the above ideas. The increased gun reliability resulting from such a mechanism is not worth the engineering effort or additional cost required to develop and produce one. However, the ideas will still be discussed.

a. Movable Rim Guides

The whole theory behind a movable rim guide is that the excessive force exerted on the rim guide during a late feeding situation would create sufficient clearance for the round to pass over the top of the rim guide. This would prevent broken rim guides and gun stoppages cause by the late feeds.

Figures 98 through 101 illustrate various ways of producing a movable rim guide.

b. Accelerators

(1) Angle-Multiplying Mechanism

This mechanism would accelerate the round into the bolt body at all times. It is based on the same principle used for a shaper. The pin on the feeder sprocket would traverse a certain predetermined arc length while the accelerator would travel a greater arc length during the same time period. A kicker would be mounted on the inside surface of the feeder forward inner guide as shown in Figure 102. One of the pins on the feeder sprocket would engage the track of the kicker and push the kicker 180 degrees, where another pin would engage the track. The pins would engage and disengage the kicker every 72 degrees of feeder sprocket rotation.

The difficulty in employing such a device lies in the interference that exists between the kicker and the feeder shaft. Reduction of the shaft's size would overcome this problem, but would jeopardize the required strength of the shaft.

(2) Spring Lever Mechanism

The spring lever mechanism shown in Figure 103 ensures that the rounds are in the head bolt extractor lip at all times during handoff. The mechanism consists of a lever and a spring. The top surface of the head bolt travels along the cam of the lever (kicker) and activates it, causing the lever arm to push the round into the head bolt. The head bolt directly controls the position of the lever, independent of the feeder sprocket.

(3) Solenoid Kicker

This mechanism is different from the others previously discussed. The other mechanisms would work at all times, regardless of early or late feed. The solenoid kicker mechanism (see Figure 104) would operate only when a late feed situation existed. The head bolt would push the round against the rim guide and cause a microswitch to actuate a miniature solenoid. The solenoid kicker would accelerate the round into the head bolt, at which time the microswitch would be turned off and the kicker would return to its original position.

Some of the problems with this type of device are the feasibility of producing such a small solenoid with the required characteristics and the reliability and time delays involved with the use of such an electrical system.

A P P E N D I X   IV-A

Illustrations

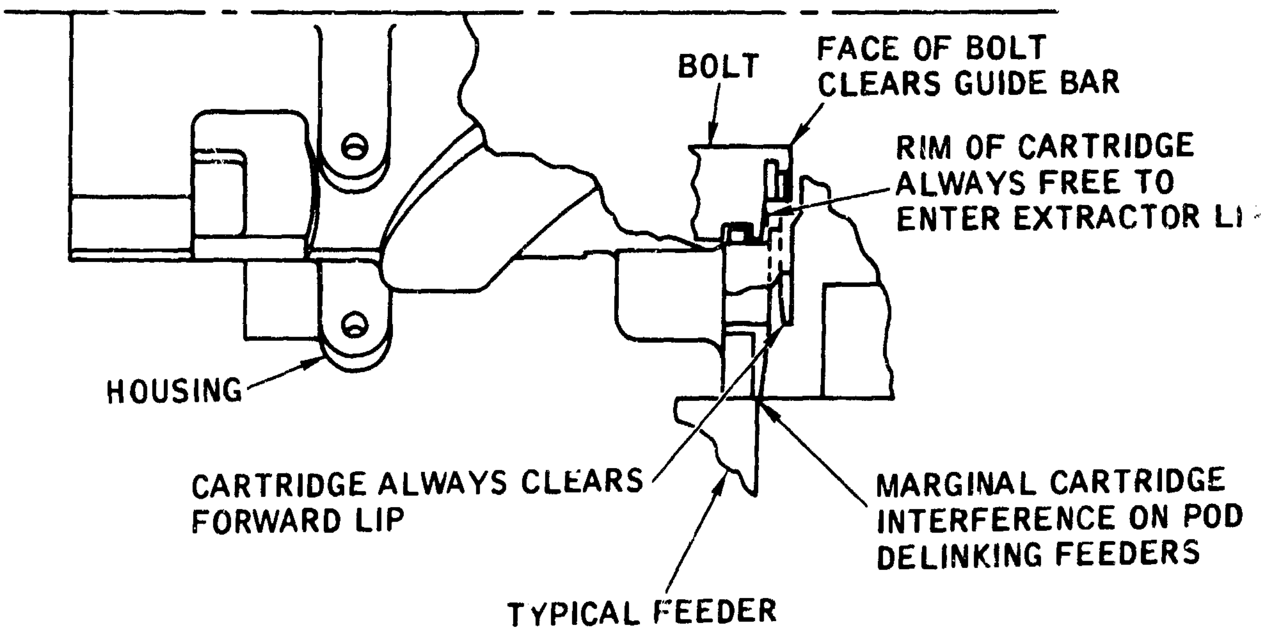


Figure 95. Cartridge Handoff - Feeder/Guide Bar/ Head Bolt

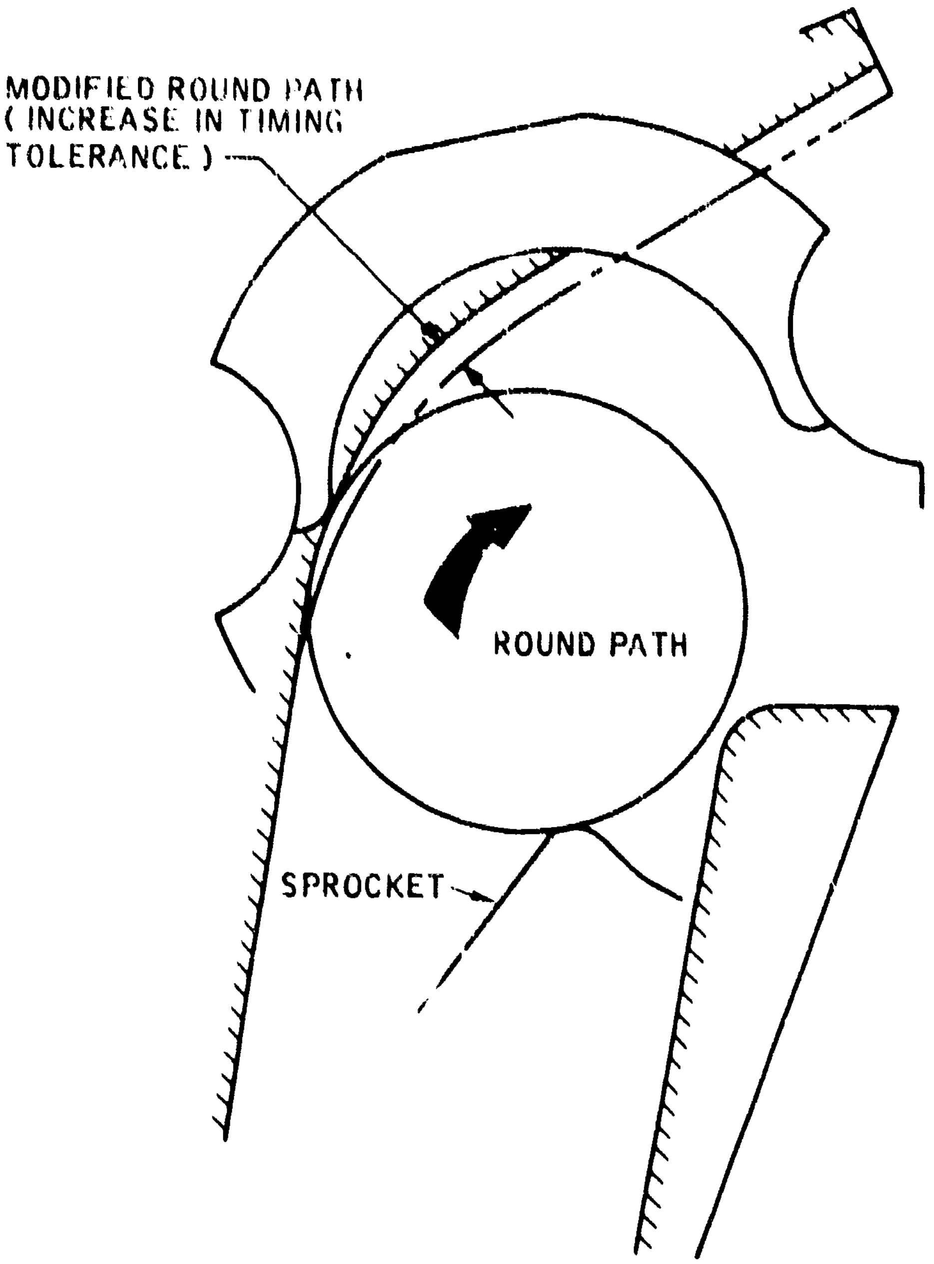


Figure 96. Modified Round Path

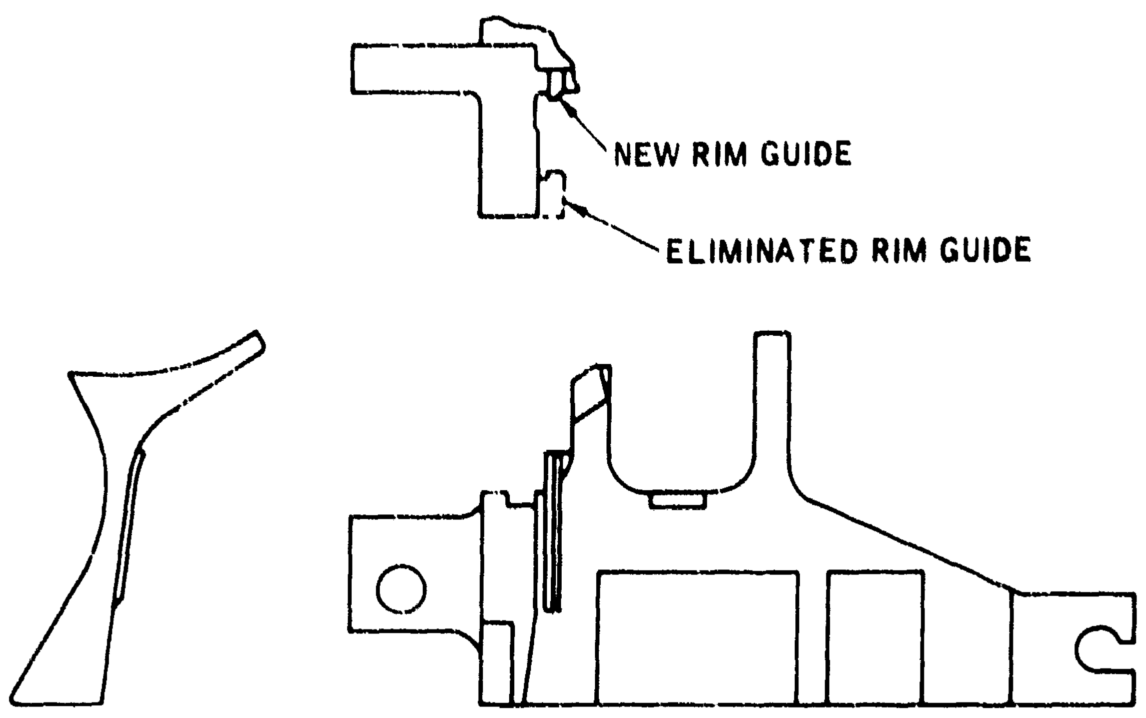


Figure 97. New Rim Guide

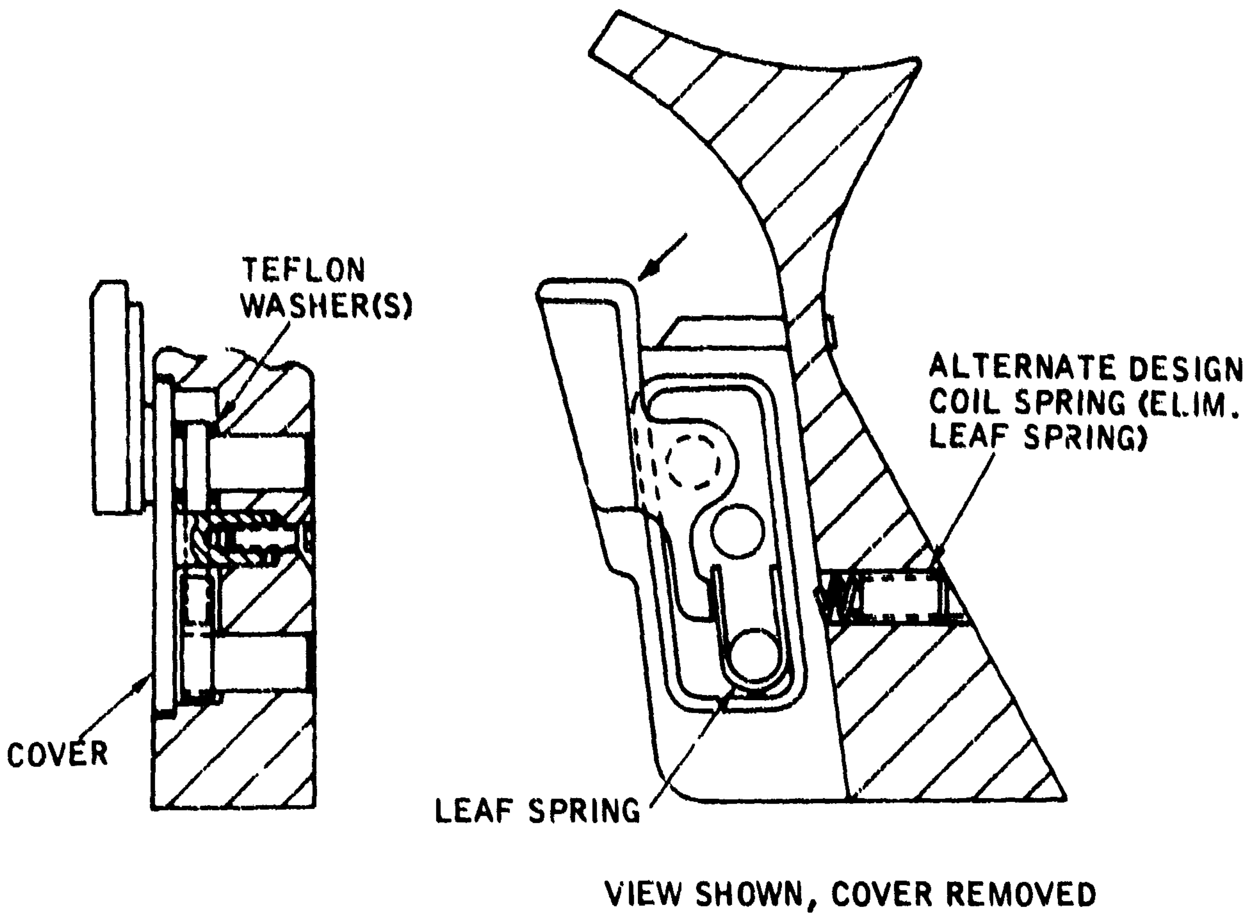


Figure 98. Guide Bar, Adjustable Rim Guide

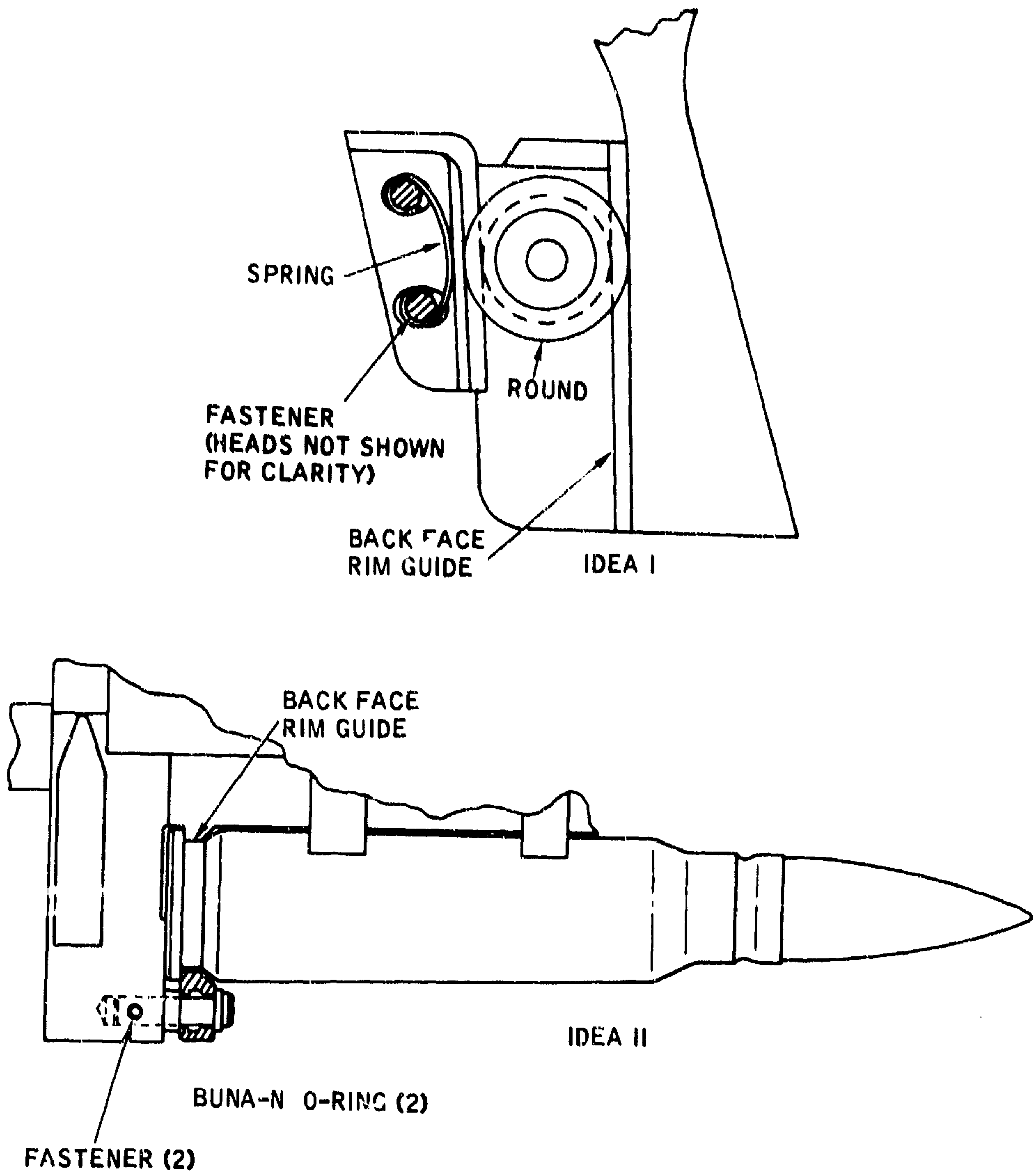


Figure 99. Guide Bar Back Face Rim Guide, Feeder Side Self-Adjusting for Excess Loading

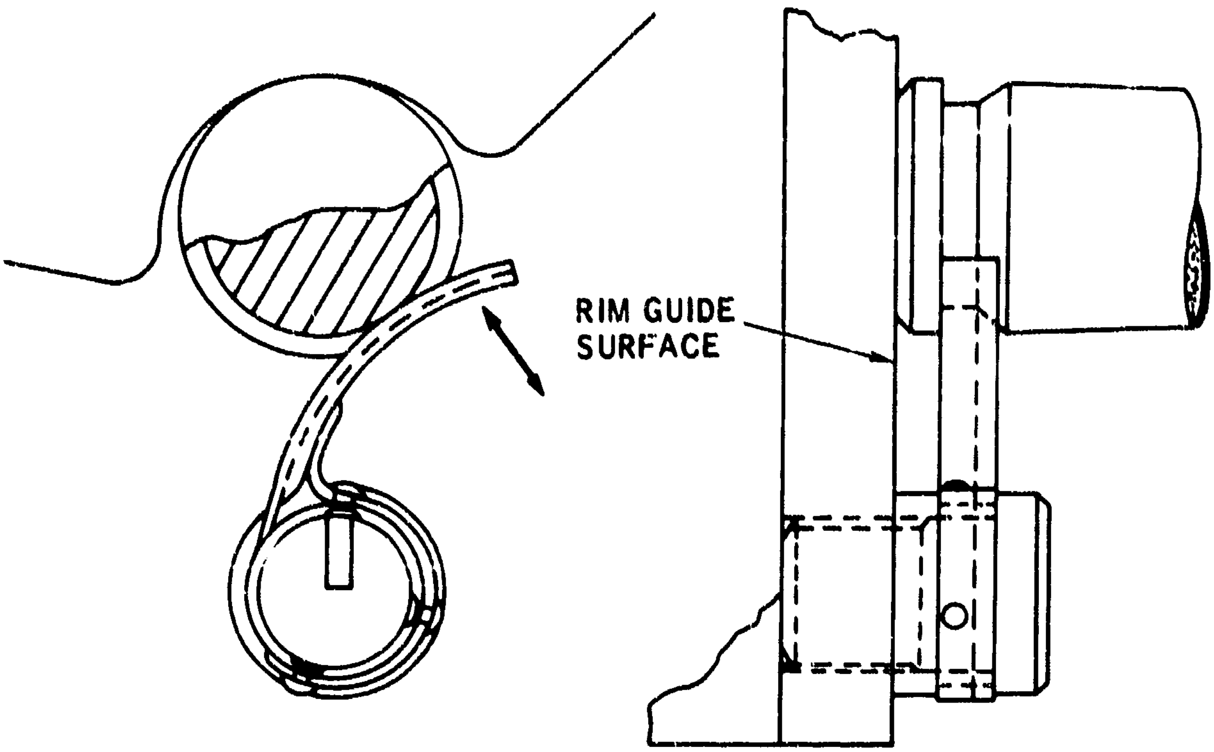


Figure 100. Spring Rim Guide

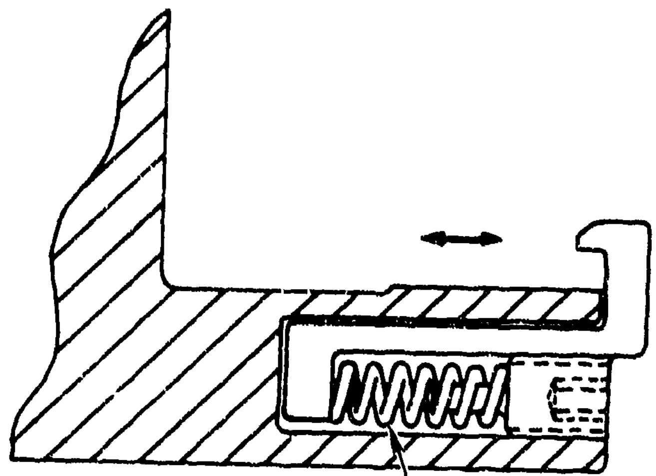


Figure 101. Spring-loaded Rim Guide

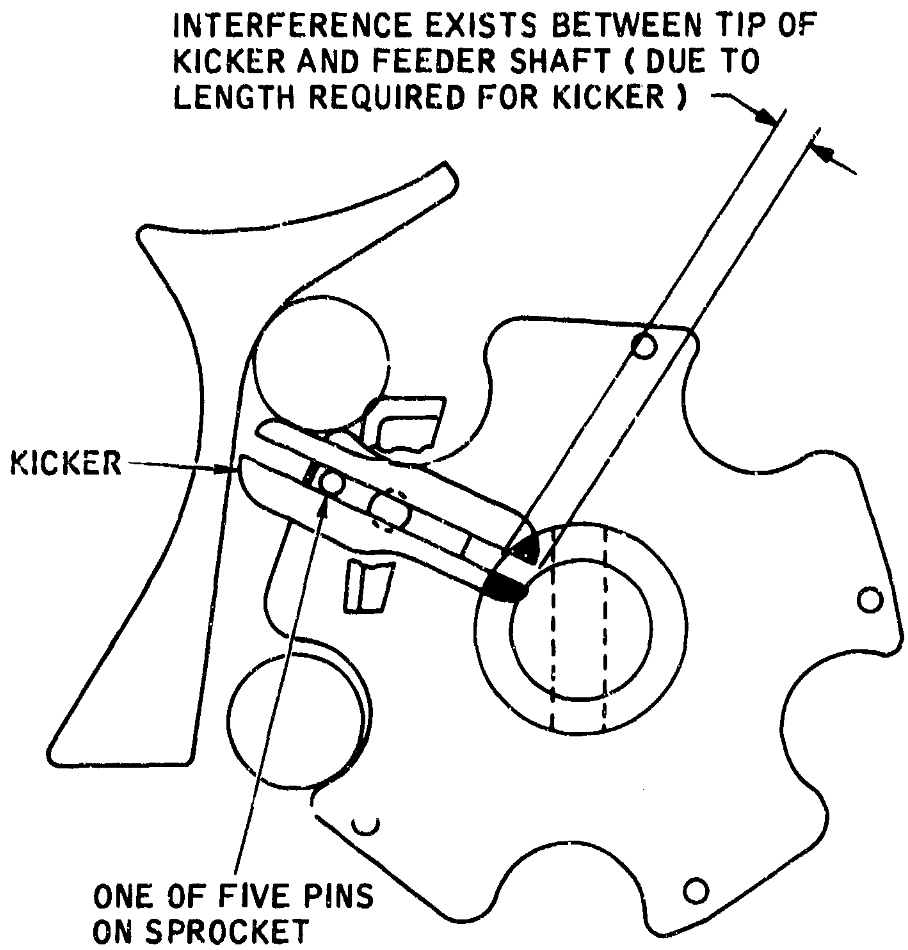
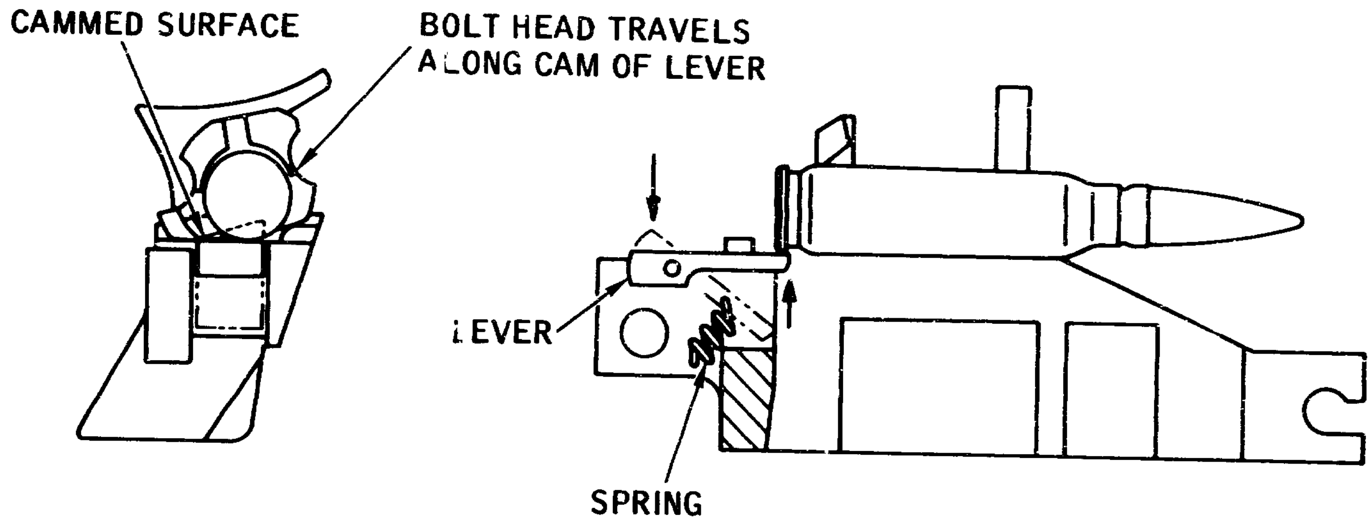


Figure 102. Angle-Multiplying Mechanism



HEAD BOLT TRAVELS ALONG CAM OF LEVER AND CAUSES LEVER ARM TO PUSH RIM OF ROUND INTO BOLT HEAD EXTRACTOR LIP AS SHOWN.

Figure 103. Spring Lever Mechanism to Control Round

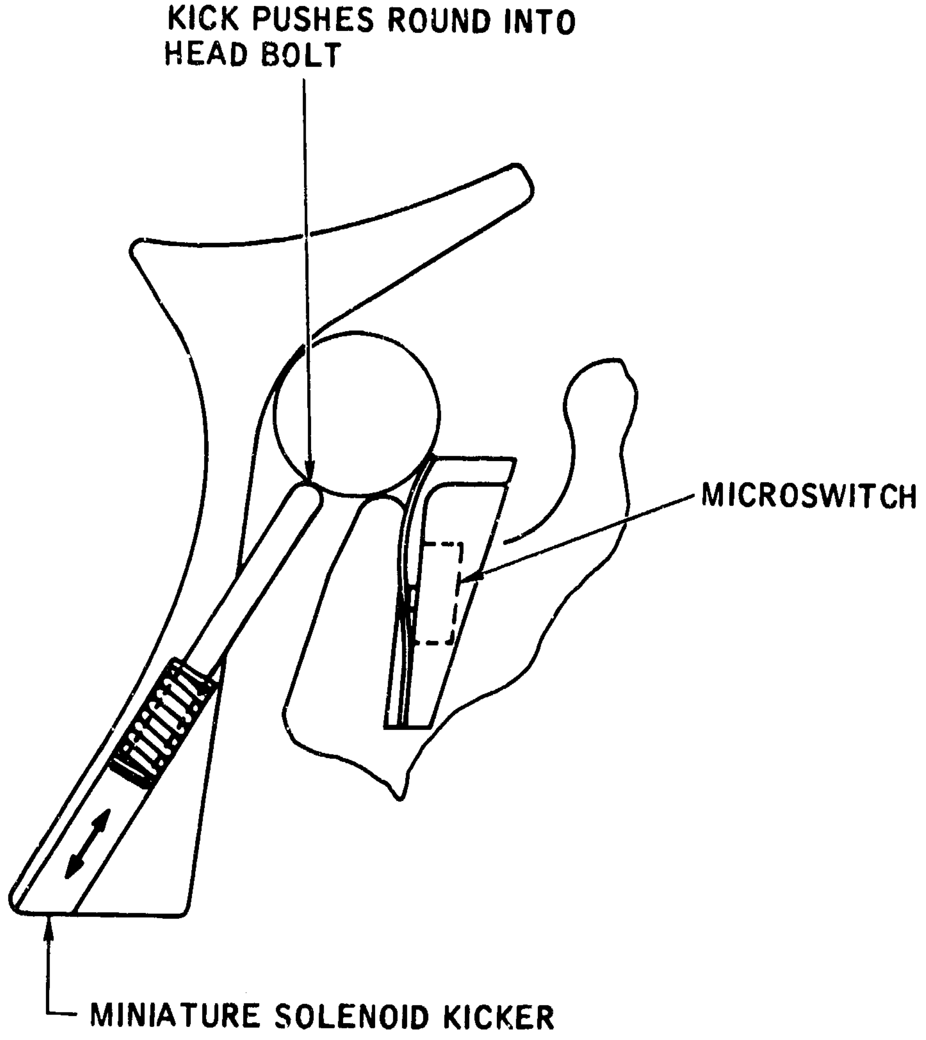


Figure 104. Solenoid Kicker

A P P E N D I X IV-B

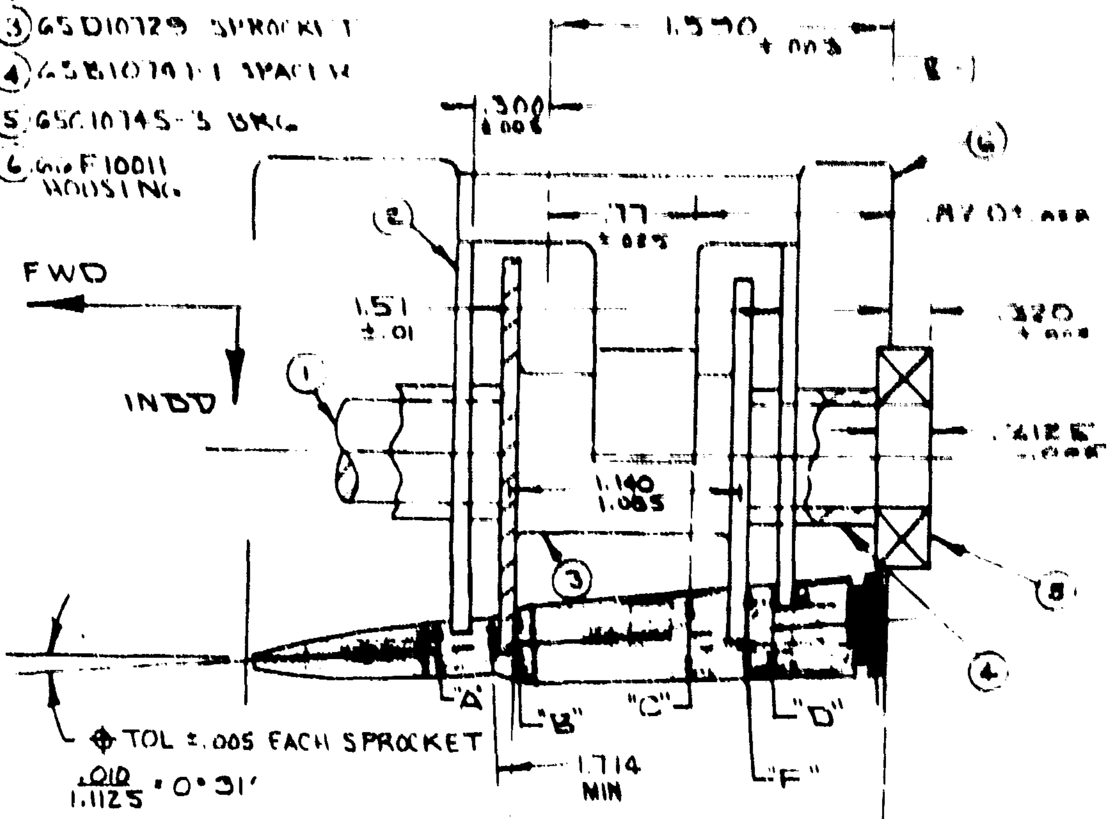
Tolerance Study

TECHNICAL ANALYSIS FORM

BY R. J. WEINERT CK. DATE 11/5/68 REV. C	GENERAL ELECTRIC	PAGE 1/44 MODEL MAU 100/13 REPORT "MINI"

LOCATION OF RIDING DIA'S, FWD TO REAR

1. 65B10157 SHAFT
2. 65D10715 GUIDE
3. 65D10729 SPROCKET
4. 65B10781-1 SPACER
5. 65C10745-5 BRG.
6. 65F10011 HOUSING



$\frac{.010}{1.1125}$ = 0° 31'

DIA "A" = .343 NOM

LOC. 1.550
.300
1.850

DIA "B" = LOCATION 1.1800 SPROCKET MIN 1.210 MAX
.4990 SPACER MIN .503 MAX
+ .3075 BRG MIN + .3175 MAX
1.9865 MIN STACK 2.0305 MAX
− .3220 MAX C'BORE − .3186 MIN
1.6645 MIN LOCATION 1.7125 MAX
1.634 TAPER
.030 × TAN 20° =
.0109 × 2 = .0218

.400 DIA
.0153
.385 RIDING DIA
MIN LOC SPROCKET

1.714 MAX LOC 20° ∡
1.712
.002 FROM TAPER INTERSECTION

DIA "B" = .3850/.3435

.3435 DIA MAX LOC

DIA "C" = LOCATION .820 NOM
1.56 LOC OF TAPER
− .82 LOC
.74 = 1 : .012 = .74 : "C" = .74 × .012 = ∡ = .0089

.454 − .006 TAPER DIA
.009 TAPER
.460 ± .003 = DIA "C"

024-000 (8-00)

TECHNICAL ANALYSIS FORM

BY R J HEBERT CK DATE 1/6/68 REV. D	GENERAL ELECTRIC	PAGE 2/44 MODEL MAU 100/B REPORT "MINI"

DIA "D" + LOCATION 1.890 + 1.56 TAPER

1.520 .37 LG

.370 1.19

D = 1.1 .012 × 1.19 ("D") .454 .006 TAPER DIA

.012 .019

.014 .465 ±.002 DIA "D"

DIA "E" LOCATION = .145 - .030

.501 - .002

+ .3125 - .005

.9585 - .037

- .3200 - .005

.6385 - .035 "A"

.0175

.6210 ± .035

1.56 LG OF TAPER

.621

.939

1.1 .012 × .930 "E"

.012

.01126

.459

.462 ± .002 DIA "E"

RESULT:

FWD SPROCKET (SHADED) ALWAYS RIDES ON 20° INCLINE OF CARTRIDGE THUS EXERTING AN AFT AXIAL FORCE INTO FEEDER (SURFACE E) GUIDE BAR AND BOLT HD.

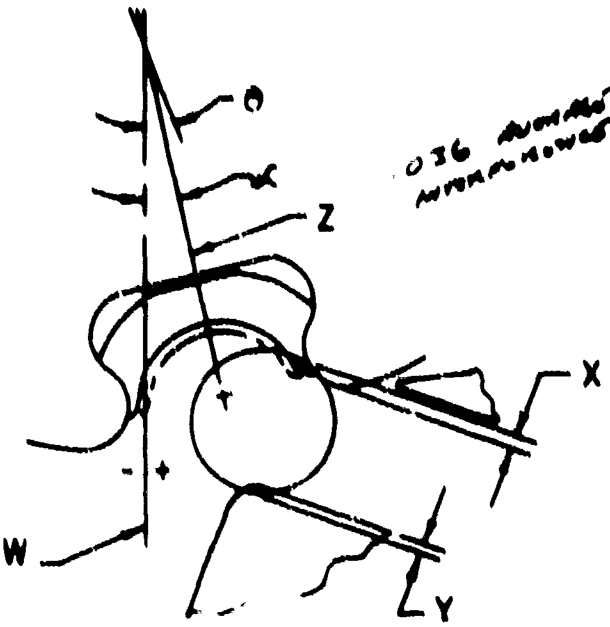
ROUND CAN TIP INBD OR OUTBD BY 0°31' MAX SHOWN ON PG 1.

004-000 (0-00)

PAGE 3A/44

EARLY FEED CARTRIDGE INTERFERENCE (ACTUAL NOMINAL CONDITIONS) FOR MAU-56A FEEDER

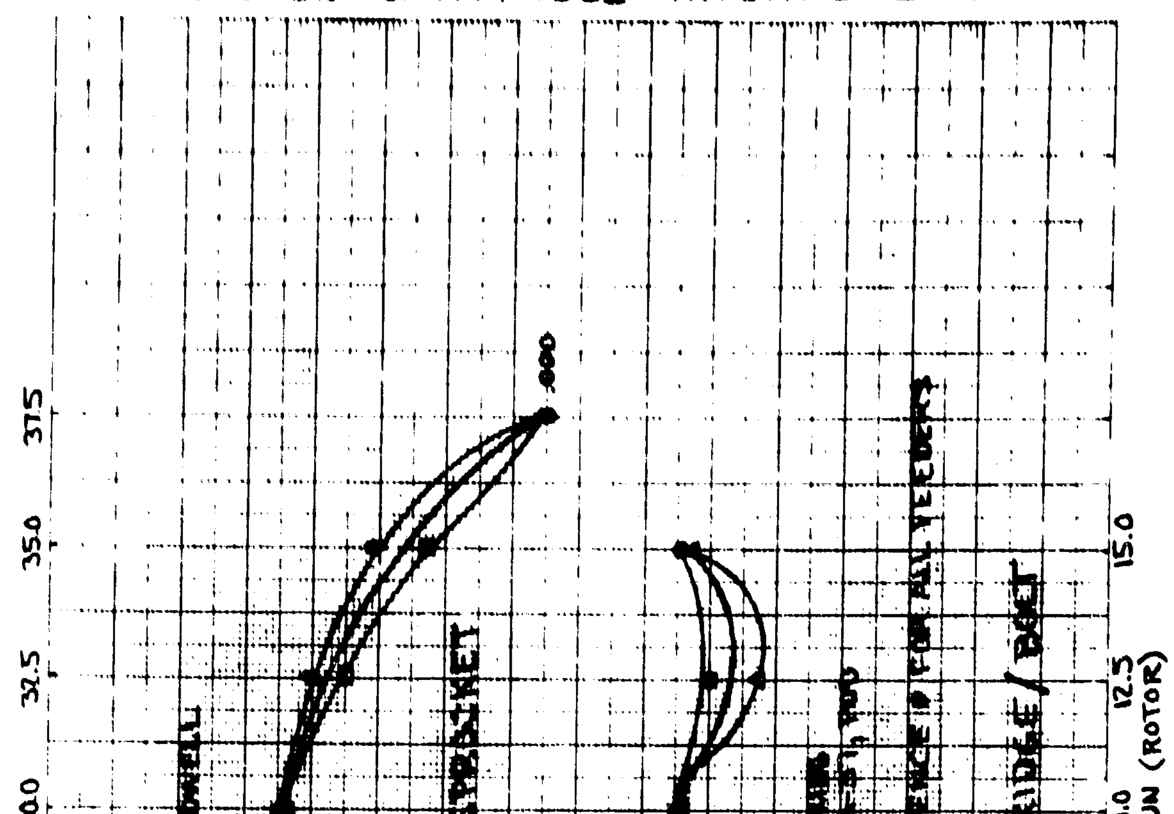
W=180° DWELL
X=INTERFERENCE CARTRIDGE/BOLT
Y=INTERFERENCE CARTRIDGE/SPROCKET
Z=BOLT CENTERLINE



α	X MIN/MAX	Y MIN/MAX	θ (3)
-2.5	.000		
.0	.000/.012		.75
+2.5	.014/.023		1.00
5.0	.030/.039		2.25
7.5	.035/.048	.000 nominal	2.5
10.0	.036/.050		2.5
12.5	.038/.042		2.00
15.0	.039/.046		2.00
17.5		.010/.015	1.25
20.0		.015/.022	.50
(1) 22.5	.032 nominal	.015/.025	2.5 INTERFERENCE
(2) 25.0		.015/.028	EXISTS WITH SPROCKET
27.5		.024/.035	THRU FEED CYCLE
30.0		.022/.031	
32.5		.015/.025	
35.0		.008/.016	
37.5		.000	

(1) CARTRIDGE SEATED, STARTS TO TRANSLATE FORWARD OUT OF DWELL.
(2) CARTRIDGE MAKES FINAL CONTACT WITH GUIDES.
(3) DEGREE OF INCREASE REQUIRED TO ELIMINATE EARLY FEED.

AVERAGE CARTRIDGE INTERFERENCE



TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 10/20/68 REV. C	GENERAL ELECTRIC	PAGE 4/44 MODEL MAU 110/B REPORT "MINI"

LOCATION OF SPROCKET ON FEEDER IN RELATION TO BOLT WHEN TIMED

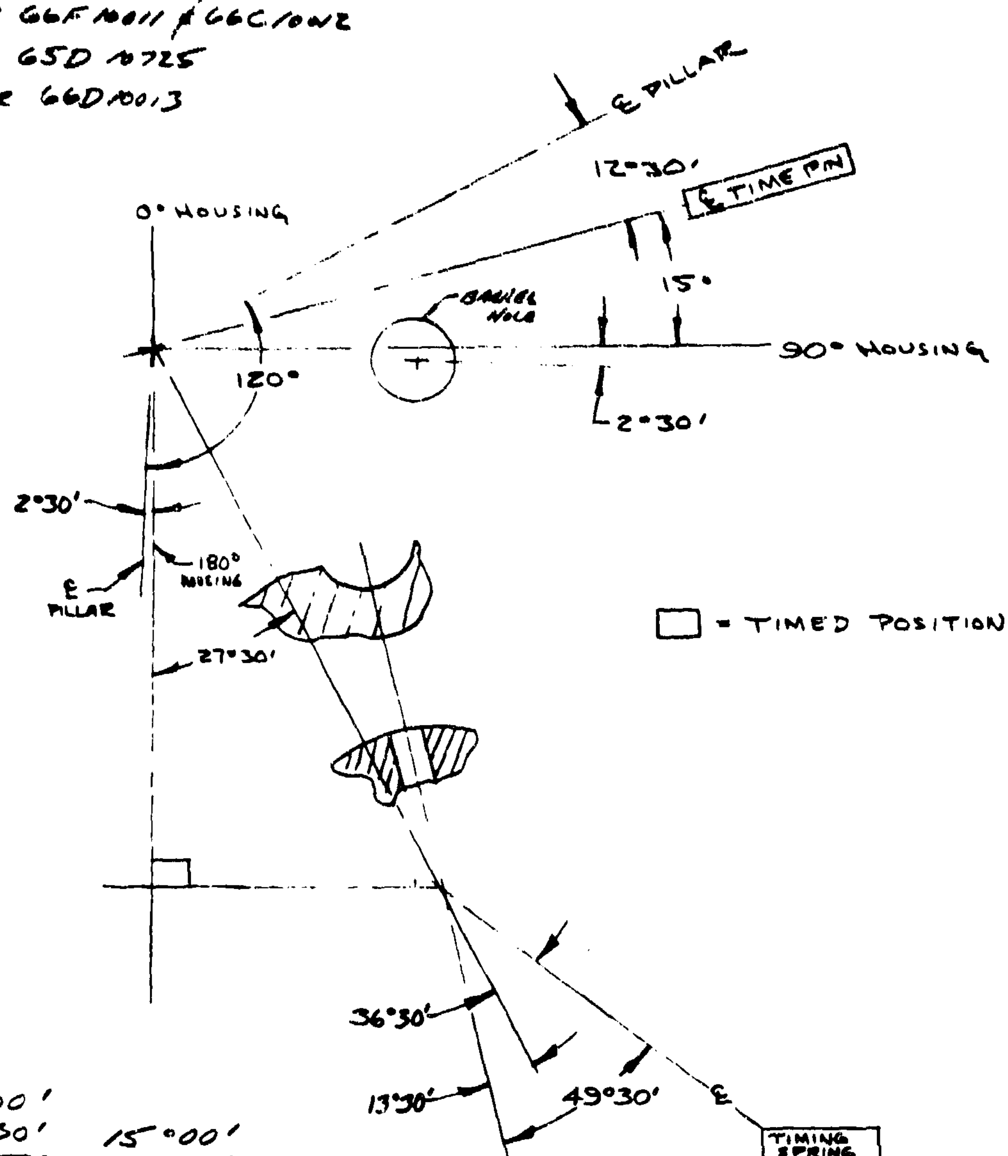
REFERENCE

H'SNG 175F842

HOUSING 66F10011 & 66C10012

GEAR 65D10725

FEEDER 66D10013



30°00'
27°30'
2°30'

15°00'
12°30'
90°00'
117°30'
120°00'
2°30'

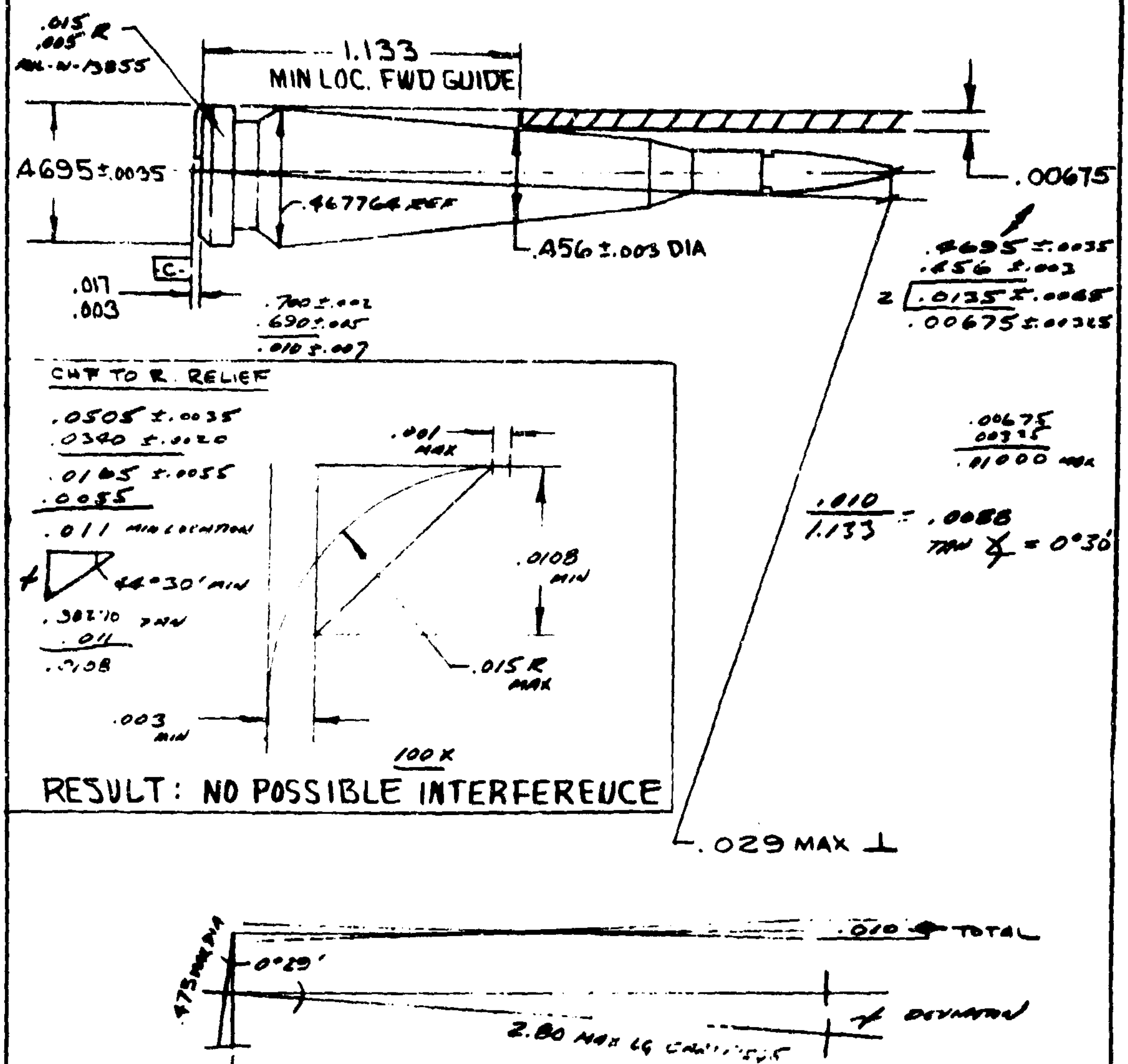
664-830 (8-60)

TECHNICAL ANALYSIS FORM

BY RJ NEBERT CK. DATE 4/6/68 REV. C	GENERAL ELECTRIC	PAGE 5/44 MODEL MAU-100B REPORT "MIN"

RELATIONSHIP OF ROUND TO GUIDE BAR

RESULT: CARTRIDGE CAN TIP INBD MAX ∡ 0°30′ DUE TO NO ALLOWANCE IN DESIGN FOR TAPER ON CARTRIDGE



RESULT: NO POSSIBLE INTERFERENCE

.4695 ±.0035
.456 ±.003
2 | .0135 ±.0065
.00675 ±.00325

.00675
.00325
.01000 MAX

$\frac{.010}{1.133} = .0088$ TAN ∡ = 0°30′

.0505 ±.0035
.0340 ±.0020
.0165 ±.0055
.0055
.011 MIN LOCATION

.3020 TAN
.011
.0108

.700 ±.002
.690 ±.005
.010 ±.007

$\frac{.004}{.473}$ = SINE = 0°29′

.0089 SINE
2.8
.02356
.00500
.02856 .029 MAX ⊥

.702 - .004

RESULT: ∡ 0°36′ CANCELLED DUE TO SPROCKET (PG 2 REF)

$\frac{.029}{2.80}$ = SINE = 0°36′ ∡ TO GUIDE DATUM B

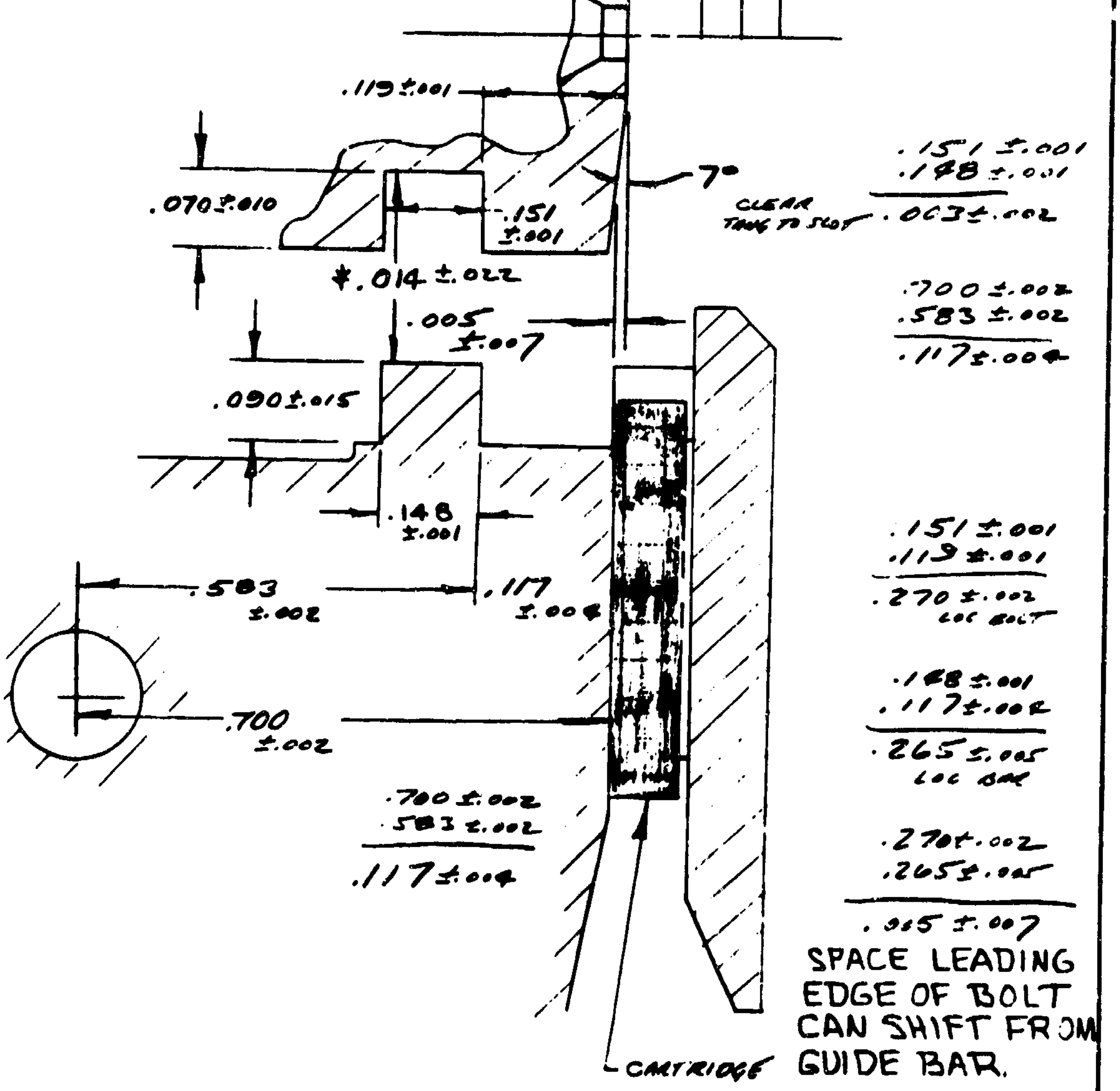
684-000 (6-60)

TECHNICAL ANALYSIS FORM

BY R J [illegible] CK. DATE 11/13/[illegible] REV. C	GENERAL ELECTRIC	PAGE [illegible]/44 MODEL [illegible] 100/15 REPORT "[illegible]"

GUIDE BAR TANG / BOLT [illegible] (REF ANGLE 7)

RESULT: NO INTERFERENCE. CARTRIDGE IS GUIDED BY 7° TAPER ON BOLT IN WORST CONDITION



* SEE REFERENCE CHECKS

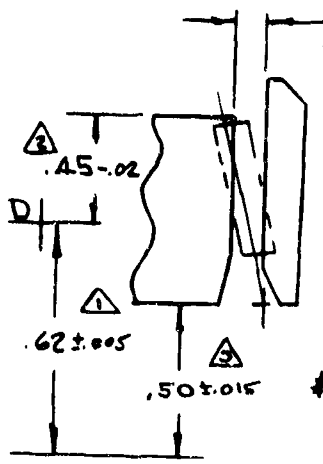
[illegible] (8-60)

TECHNICAL ANALYSIS FORM

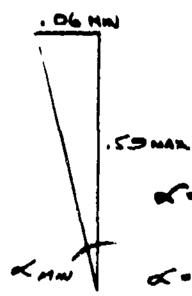
BY RJ HEBERT CK. DATE 11/6/68 REV. E	GENERAL ELECTRIC	PAGE 7/44 MODEL REPORT "MINI"

CHECK OF CARTRIDGE CLEARANCE IN BAR TRACK & BOLT LIP

REF BOLT HD 65F3087



$\triangle 1$ .620 ±.005
$\triangle 2$ .440 ±.010
1.06 ±.015
$\triangle 3$ .50 ±.015
.56 ±.03

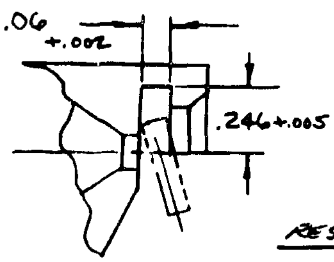


$\alpha = \frac{.06}{.59}$ TAN
.10107
$\alpha = 5°46'$

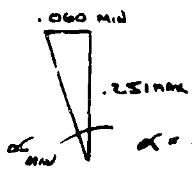
RESULT

WHILE PASSING THROUGH SLOT SPROCKET EXIBITS *0°31' MAX ∡ ON CARTRIDGE. THIS CAUSES NO INTERFERENCE AS SLOT CAN ACCEPT $\frac{2°16'}{0°44'}$ (SEE BELOW)

*REF PG 2



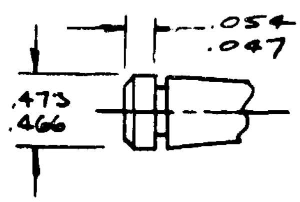
$\frac{.060 \text{ MIN}}{.251 \text{ MAX}}$ = TAN = .2390 =



$\alpha = 13°27'$

RESULT

BEFORE FULLY SEATED SPROCKET EXIBITS *0°31' MAX ∡ ON CARTRIDGE. THIS CAUSES NO INTERFERENCE AS BOLT HEAD CAN ACCEPT 0°44' MIN (SEE BELOW)



.060 MIN SLOT
.054 MAX CARTRIDGE
.006

$\frac{.006 \text{ MIN CLEAR}}{.473 \text{ MAX DIA}}$ = SINE ∡
.0126 = 0°44'

.065 MAX SLOT
.047 MIN CARTRIDGE
.018

$\frac{.018 \text{ MAX CLEAR}}{.466 \text{ MIN DIA}}$ = SINE ∡
.0386 = 2°16'

RESULT: NO INTERFERENCE ON GUIDE TRACK OR BOLT.

684-889 (8-60)

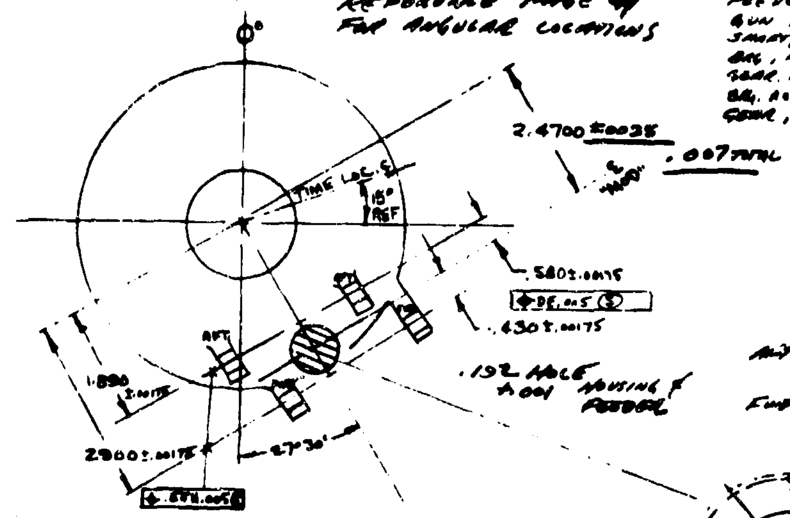
TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 11/7/68 REV. 17	GENERAL ELECTRIC	PAGE 8/44 MODEL MAU 100/18 REPORT "MAAH"

GEAR DRIVE BACKLASH

VIEW FWD

REFERENCE PAGE 4 FOR ANGULAR LOCATIONS



REFERENCE
FEED UNIT HOUSING 66F10011
GUN HOUSING 175E842
SHAFT, ROTOR 65B10737
BRG, ROTOR 65C10705-3
GEAR, ROTOR 65D10725
BRG, ROTR 65B3079
GEAR, ROTOR, AFT 65C3752

1.890 ±.00175
+ .580 ±.00175
2.470 ±.0035

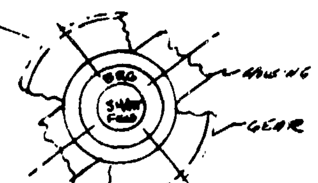
2.900 ±.00175
− .430 ±.00175
2.470 ±.0035

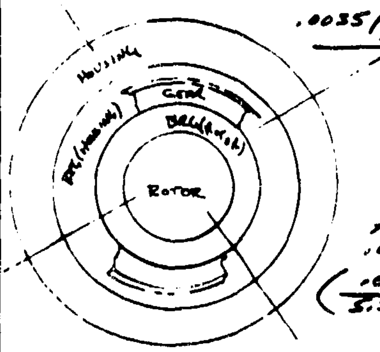
.192 HOLE ±.001 HOUSING & FEEDER

AFT PIN 65B10988 $\frac{.1885}{.1870}$ DIA

FWD PIN 65B10711 $\frac{.191}{.188}$ DIA

AFT PIN (CLOSEST TO GEARS)
.0035/.006 LOOSE





BEARING BORE .0015 MAX T
BEARING OD .0016 MAX T
TO HOUSING .0020 T
GEAR BORE .0035 MAX T
TOTAL STACK .0054

THE TOLERANCE IS CANCELLED OUT AS THE TIR IS OVER 5.25 SPAN AND THE GEAR WOULD ONLY SEE .0001 TOTAL ECCENTRICITY

$\left(\frac{.002}{5.25} = .00038 \text{ TAN} \times .38 \text{ LOC OF GEAR} = .0001 \text{ ECC.}\right)$

P.D. GEAR 2.2500
TEETH 45
PRES. ∠ 20°
TOOTH TO TOOTH ERROR .0008
TOTAL COMPOSITE TOOTH ERROR .0015
CLASS AGMA 390.01 QUAL. #9
(EQUIV. TO COMMERCIAL 4)
DIAMETRICAL PITCH = 2

BRG. ROTOR BORE .0015 MAX — ⓘ .0013 TIR
BRG. ROTOR O.D. .0025 MAX — ⓘ .002 TIR
GEAR BORE .0012 MAX

STACK UP TOL .0052 MAX

THE TOLERANCE IS CANCELLED OUT AS IN THE WORST CONDITION THE GEAR WOULD ONLY SEE .00017 TOTAL ECCENTRICITY (THE TOTAL ECCENTRICITY IS OVER A 8.055 SPAN)

P.D. GEAR 2.700
TEETH 54
PRES. ∠ 20°
TOOTH TO TOOTH ERROR .0008
TOTAL COMPOSITE TOOTH ERROR .0015
CLASS AGMA 390.01 QUAL. #9
(EQUIV. TO COMMERCIAL 4)
DIAMETRICAL PITCH = 2

$\frac{.002}{8.055} = .00025 \text{ TAN} \times .42 \text{ LOC OF GEAR} = .0001 \text{ ECC.}$

$\frac{.0013}{8.055} = .00016 \text{ TAN} \times .42 \text{ LOC} = .000067 \text{ ECC.}$

MAX TOL IN GUN AT GEAR LOC .0052
MAX TOL IN FEED AT GEAR LOC .0054
MAX TOL IN REAR PIN .0060
MAX TOTAL .0166 (OR ±.0083)

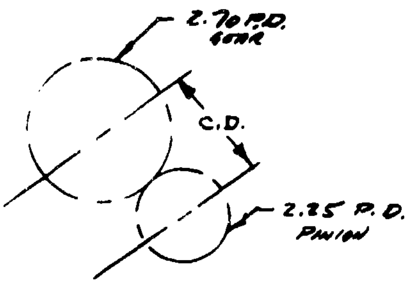
004-030 (8-60)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 11/7/68 REV. C	GENERAL ELECTRIC	PAGE 9/44 MODEL MAU 110/B REPORT "MINI"

GEAR DRIVE BACKLASH (CONT)

CENTER DISTANCE



$$C.D. = \frac{P.D.\ PINION + P.D.\ GEAR + (2 \times T.I.C.E.)}{2}$$

$$C.D. = \frac{2.25 + 2.70 + (2 \times .0015)}{2}$$

C.D. = 2.250
2.700
.003
2 | 4.953
C.D. = 2.4765 ULTIMATE DESIGN

SHEET 8 ILLUSTRATES C.D. = 2.4665/2.4735 ON PARTS ±.0035
THIS RESULTS IN A INTERFERENCE OF
2.4765 2.4765
2.4665 2.4735
.0100 MAX .0030 MIN
INTERFERENCE

WE SHALL RETURN TO THIS AFTER OTHER CONSIDERATIONS

CENTER DISTANCE CHANGE & BACKLASH

FROM SHEET 8 WE HAVE VARIATIONS OF C.D. CHANGE AS FOLLOWS:

PIN .0060 LOOSE MAX (.0035 MIN)
FEEDER .0054 MAX
GUN .0052 MAX

.0166 TOTAL C.D. CHANGE IN PARTS
.0070 TOTAL C.D. CHANGE IN SUB-ASSYS
.0236 TOTAL C.D. CHANGE

INTERFERENCE AS SHOWN ABOVE IS .010 / .003 THUS CHANGING OUR "C.D. CHANGE" TO =

.0236 .0236
.0100 .0030
.0136 MIN .0206 MAX

BACKLASH = C.D. CHANGE × (2 × TAN 20° PRESS. ∡)
= C.D. CHANGE × (2 × .36397) = C.D. CHANGE × .72794

BACKLASH MIN = .0136 × .72794 = .010 BACKLASH MAX = .0206 × .72794 = .015

NOTE: ASA B6.6-1946 SUGGESTS .030 / .016 BACKLASH

REMEMBERING THIS IS 100% MAX TOLERANCE CONSIDERATION, WE SHALL NOW LOOK AT THIS FROM A STATISTICAL TOLERANCE APPROACH AND ASSUME THAT ONLY 70% OF THE MAX. TOL. WILL EVER EXIST. THIS REDUCES OUR BACKLASH TO

.010/70% = .007 MIN .015/70% = .0105 MAX

664-000 (8-60)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 4/7/68 REV. B	GENERAL ELECTRIC	PAGE A/44 MODEL [illegible] REPORT "[illegible]"

GEAR DRIVE BACKLASH IN RADIANS

BACKLASH IN RADIANS = $\frac{180}{\pi}(\gamma)$ BASED ON 70% TOL (PAGE 6)

$\gamma = \frac{.0105 \text{ MAX BACKLASH}}{1.125 \text{ RADII FEED}} = .00935$ $\frac{.007 \text{ MIN}}{1.125} = .00622$

$\frac{180}{\pi} = 57.3$

$\gamma = .00935$, $\times 57.3$, $.534°$, $\gamma = 0°32'$ MAX

$\gamma = .00622$, $\times 57.3$, $.356°$, $\gamma = 0°21'22''$ MIN

BACKLASH IN RADIANS = $\frac{180}{\pi}(\gamma)$ BASED ON 100% TOL (PAGE 6)

$\gamma = \frac{.015 \text{ MAX BACKLASH}}{1.125 \text{ RADII FEED}} = .01327$ $\frac{.010 \text{ MIN}}{1.125} = .00893$

$\frac{180}{\pi} = 57.3$

$\gamma = .01327$, $\times 57.3$, $.761°$, $0°45'40''$ MAX

$\gamma = .00893$, $\times 57.3$, $.512°$, $0°30'45''$ MIN

[illegible] (6-66)

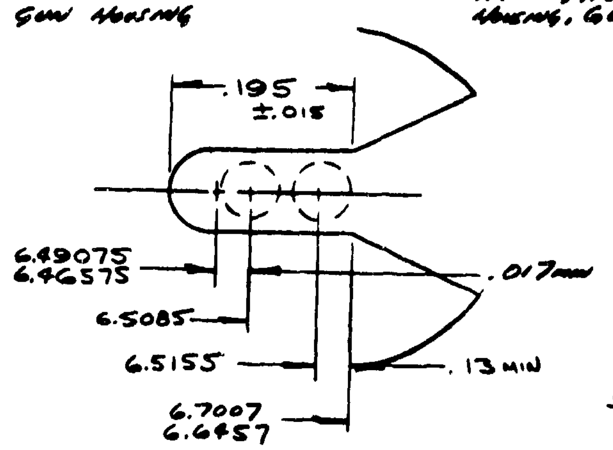
TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 11/12/68 REV. B	GENERAL ELECTRIC	PAGE 11/44 MODEL MAU-58 (A-37) REPORT "MINI"

MODULE FEED & A-37 FEED, DIFFERENCES

CHECK SEATING OF FEEDER HOUSING TO GUN HOUSING

REF
HOUSING, FEED 67F12307 2/3
HOUSING, GUN 66F10011



6.5085
6.4907
.0178 MIN

6.6457
6.5155
.1302 MIN

RESULTS

FEEDER ALWAYS SEATED IN SLOT 11 TO ℄ SPROCKET.

REF BEARINGS 65C10745-3 GUIDE, FEEDER 66D12251
SHAFT 65B10737
GEN, FEEDER 65D10725

MOUNTING DIMENSIONS AND PARTS LISTED ARE SAME AS MODULE FEEDER THUS RESULTING IN SAME BACKLASH (PG 7)

ALSO ALL GUIDES ARE LOCATED IN SAME POSITIONS AS MODULE. THE GEOMETRY OF MODULE GUIDES AND HOUSING IN GUIDE BAR AREA ARE IDENTICAL.

064-000 (3-50)

TECHNICAL ANALYSIS FORM

BY R.J. [illegible] CK. DATE [illegible] REV. B	GENERAL ELECTRIC	PAGE 12/44 MODEL [illegible] REPORT "[illegible]"

BACKLASH

GR DP. 3 616

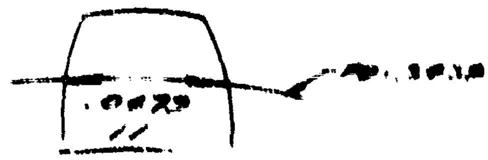
BACKLASH = PD. 1.3010
[illegible] (SPLINE)

25/328
94848
125664
30188

1.08008208
1.05380000

N MIN .02620208

.00238028 BACKLASH NOMINAL



.0079
11
.0079
.0079
.5283 [illegible]
1.0538

EFFECTIVE SPACE .0503
EFFECTIVE TOOTH .0479

BACKLASH/[illegible] .0024 NOMINAL

INVOLUTE PROFILE ERROR +.0002 -.0002

(SPROCKET) BACKLASH = .0026 MAX / .0022 MIN

.0024 NOM	.0024 NOM
+.0002 (+)	-.0002 (-)
.0026 MAX	.0022 MIN

NOTE:
ALTHOUGH THIS CALCULATED BACKLASH IS THEORETICAL THE COMPOSITE ERRORS (INDEX, [illegible], PROFILE) TAKEN INTO CONSIDERATION SHOULD RENDER THE PRACTICAL BACKLASH FOR THIS APPLICATION AS .000, FURTHER THE PHYSICAL ASSEMBLY MAY ELIMINATE BACKLASH. *

BACKLASH EFFECT OF ROTOR/GEAR = .0052 MAX (REF PG 8)

BACKLASH EFFECT OF FEEDER/GEAR =

BEARING BORE	.0007	MAX TOL.
BEARING OD	.0014	MAX TOL.
GEAR BORE	.0015	MAX TOL.
	.0036 MAX	

* IT SHOULD BE ASSUMED THAT SPLINE BACKLASH CAN OCCUR THROUGH WEAR AND ASSEMBLY PRACTICE THEREBY INCREASING BACKLASH ON PAGE 12 TO FIGURES SHOWN ON PAGE 12A.

004-020 (6-60)

TECHNICAL ANALYSIS FORM

BY [illegible] CK. DATE [illegible] REV. [illegible]	GENERAL ELECTRIC	PAGE [illegible] MODEL [illegible] REPORT [illegible]

[illegible]

[illegible] D. [illegible] [illegible] MAX = .0355 ([illegible])
MIN = .0[illegible]1

[illegible] MAX = .0383 ([illegible])
MIN = .0[illegible]

[illegible] = C.D. [illegible] = ([illegible])

.01[illegible] .027[illegible]

$\frac{180}{\pi}(1) = 57.3$

MAX = $\frac{.028}{1.125} \times 57.3 = 1.[illegible]26[illegible]°$

1°25'38"

MIN $\frac{.018}{1.125} \times 573 =$ 0°55'00"

1.125) 1.018 = .0163

573 × .016 = .9168°

TECHNICAL ANALYSIS FORM

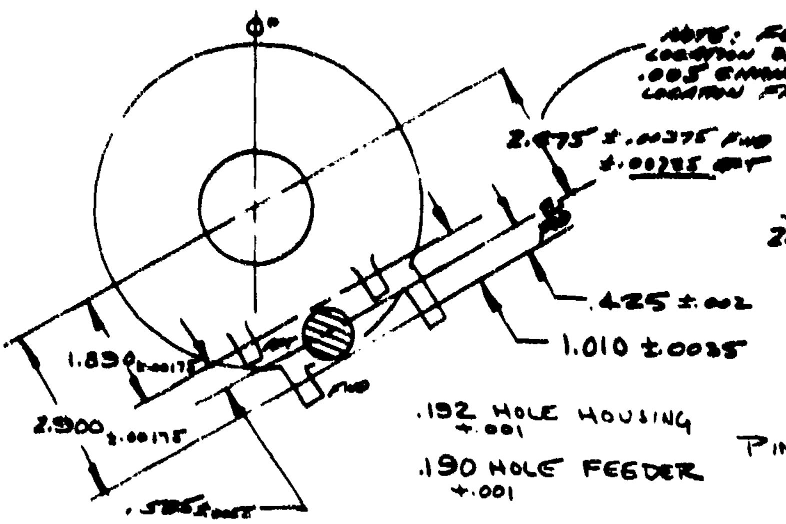
BY RJ HEWETT CK. DATE 4/12/60 REV. A	GENERAL ELECTRIC	PAGE 13/44 MODEL FWD FEEDER REPORT "[illegible]"

BACKLASH

REFERENCE

SPROCKET ASSY. AFT	63C10831
SPROCKET ASSY. FWD	63C10830
BEARINGS	65B0923
SHAFT	63C10861
HOUSING, FEED	63C10833
COVER	63C10812

NOTE: FEEDER HOUSING LOCATION DIM. COMPENSATES FOR .005 CHANGE MAKING IT SAME LOCATION FROM ℄ AS "MODEL"



2.300 ±.00175
.425 ±.00200
2.475 ±.00375

1.010 ±.0035
.425 ±.0020
.585 ±.0055

.192 HOLE HOUSING +.001

.190 HOLE FEEDER +.001

PINS $\frac{.1885}{.1870}$ DIA

1.830 ±.00175
.585 ±.0055
2.475 ±.00725

AFT PIN (CLOSEST TO GEARS) .006 LOOSE (MAX)

CENTER DISTANCE (ULTIMATE DESIGN) OF GEARS 2.4765 (SEE PG 9)

ACTUAL C.D. OF PARTS 2.475 ±.00725

2.47650	2.48375 MAX
2.46925 MIN	2.47650
.00725 MAX INTERFERENCE	.00625 MAX CLEARANCE

VARIATION OF C.D. CHANGE (PG)

PIN .0060 LOOSE MAX
FEEDER .0036
GUN .0052
.0148 TOTAL C.D. CHANGE IN PARTS
.0145 TOTAL C.D. CHANGE IN SUB-ASSYS (.00725)
.0293 TOTAL C.D. CHANGE
.0072 INTERFERENCE
.0221

.0293
.0062
.0355

.0355/.0221 C.D. CHANGE

684-[illegible] (8-60)

TECHNICAL ANALYSIS FORM

BY RJHEBERT CK. DATE 11/12/60 REV. A	GENERAL ELECTRIC	PAGE 19/44 MODEL ASA 2VTR REPORT "MINI"

BACKLASH, GEAR DRIVE FEEDER

BACKLASH = C.D. CHANGE x (2 x TAN 20° PRESS ∡)

= C.D. CHANGE x (2 x .36397 = C.D. CHANGE x .72794

BACKLASH MIN = .0221   BACKLASH MAX = .0355

$$\frac{\times .72794}{.01608} \quad \underline{\underline{.016}} \qquad \frac{\times .72794}{.0258} \quad \underline{\underline{.026}}$$

STATISTICAL TOL = $\frac{70\%}{.0112560}$ $\underline{\underline{.011}}$ $\frac{70}{.018060}$ $\underline{\underline{.018}}$

BACKLASH $\frac{.026}{.016}$ 70% TOL $\frac{.018}{.011}$

BACKLASH IN RADIANS $\frac{180}{\pi}(\measuredangle)$

$\frac{180}{\pi} = 57.3$

100% TOL

MAX = $\frac{.026 \text{ MAX}}{1.125 R \text{ FEED}} \times 57.3 = 1.329°$ MIN = $\frac{.016}{1.125} \times 57.3 = .814°$

1°19'30" MAX.   0°48'52" MIN.

70% TOL

MAX. = $\frac{.018 \text{ MAX}}{1.125 R} \times 57.3 = .917°$ MIN $\frac{.011}{1.125 R} \times 57.3 = .556°$

0°55'00" MAX   0°33'37" MIN

NOTE SEE PAGE 12A

064-880 (8-59)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 11/19/68 REV. C	GENERAL ELECTRIC	PAGE 15/44 MODEL POD REPORT "MINI"
LOCATION RIM OF CARTRIDGE/POD FEEDER/GUIDE BAR		

℄ FWD MOUNT HOLE TO RIM GUIDE FACE 3.8490 ±.0050
℄ FWD MOUNT HOLE TO NOSE GUIDE FACE −.8885 ±.0025
2.9605 ±.0075

ROUND OAL 2.7850 ±.0150

NOSE GUIDE THICKNESS .063 ±.006 CLEAR .1755 ±.0225
RIM GUIDE THICKNESS .075 ±.002 .1380 ±.0080
.138 ±.008 .0375 ±.0305
CLEARANCE HOUSING GUIDE TO CARTRIDGE

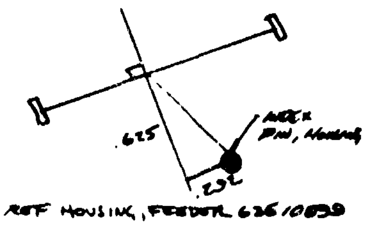
℄ TO ℄ MOUNTING HOLES 6.65120 ±.00175 (TP .005)
℄ FWD MOUNT HOLE TO RIM GUIDE ℄ 3.84900 ±.005
HOUSING RIM GUIDE TO AFT HOLES 2.6630 ±.00675
RIM GUIDE THICKNESS .0750 ±.002

LOCATION RIM OF CARTRIDGE TO AFT HOLES 2.7380 ±.00875

REFERENCE

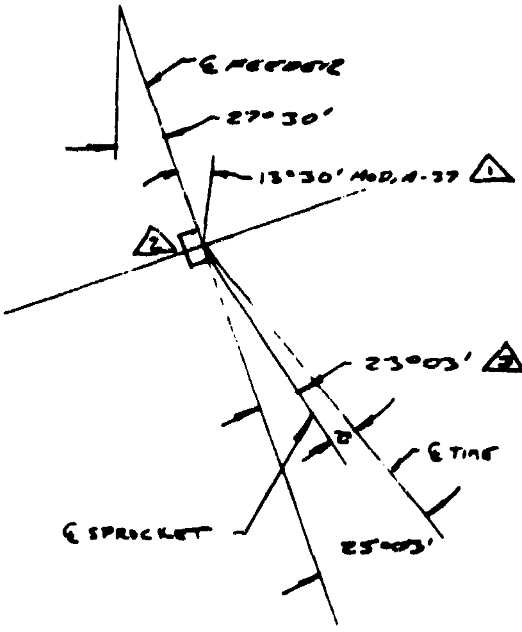
HOUSING, GUN 11631085 5/7
GUIDE, NOSE 63C10307
GUIDE, RIM 63C10303
SPROCKET, FWD 63C10830
SPROCKET, AFT 63C10831

INDEXING



REF HOUSING, FEEDER 63C10839

$\frac{.292}{.625} = .4672$ TAN = ∡ 25°03′ BASIC



RESULT

MOD-A37
1 13°30′
2 180°
3 23°03′
72° $\boxed{216°\ 33'}$ 4
3
SPROCKET TO SPROCKET

4 DIFFERENCE OF TIMING MOD A-37 TO POD = 33′ TOTAL

NO SIGNIFICANT EFFECT ON FEED CYCLE

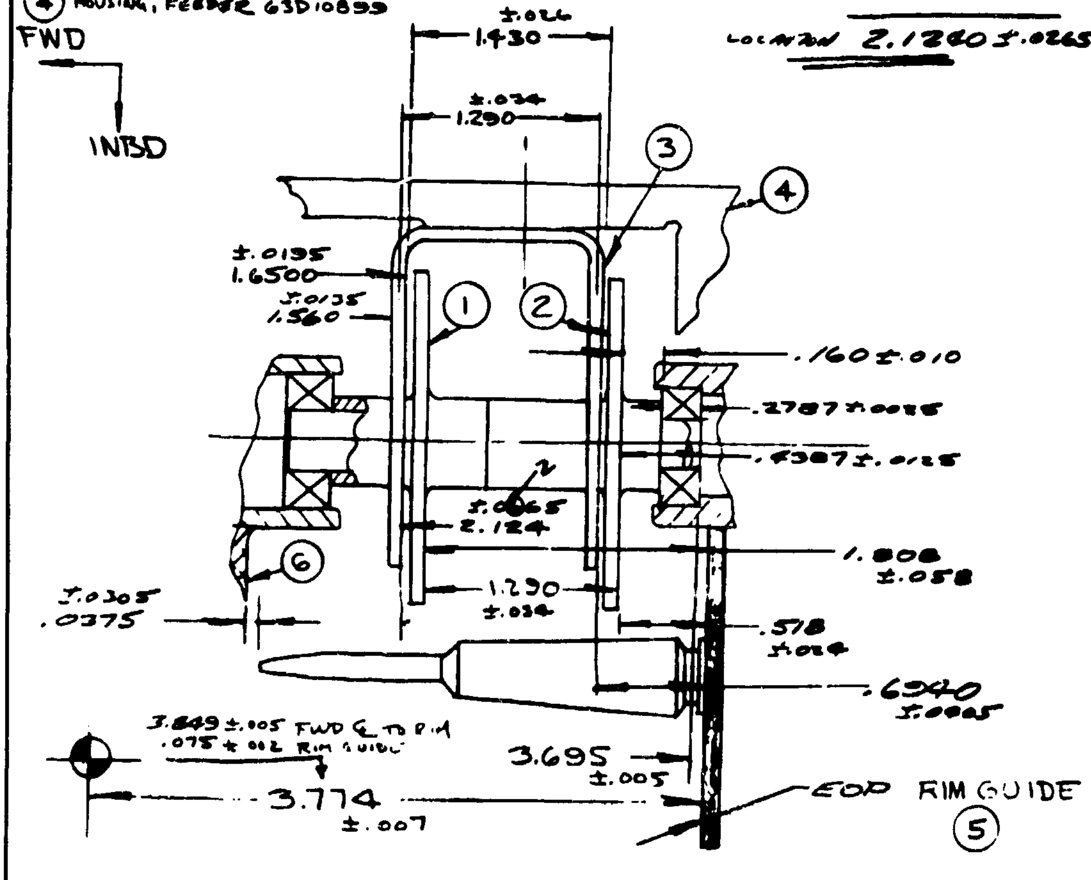
TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 11/19/68 REV. A	GENERAL ELECTRIC	PAGE 16/44 MODEL POD REPORT "MINI"

LOCATION CARTRIDGE (CONT)

1. FWD, SPROCKET 63C10890
2. AFT, SPROCKET 63C10891
3. GUIDE, INNER 63C10802
4. HOUSING, FEEDER 63D10899
5. RIM GUIDE 63C10303
6. NOSE GUIDE 63C10307

3.774 ±.0070
1.650 ±.0195
LOCATION 2.1240 ±.0265



SPROCKET WD FWD 1.015 ±.002
SPROCKET WD AFT 1.015 ±.002
2.030 ±.004
.740 ±.030
LOCATION 1.290 ±.034

EOP SPROCKET TO FACE .46 ±.01
SPROCKET TH. .12 ±.01
ELP SPROCKET TO FACE .16 ±.01
.740 ±.030

BRG WIDTH .2787 ±.0025
AFT SPROCKET TO EOP .1600 ±.010
.4387 ±.0125

℄ TO BRG C'BORE DEPTH 3.6950 ±.005
.4387 ±.0125
3.2563 ±.0175

℄ TO ROUND, RIM 3.7740 ±.0070
3.2563 ±.0175
.5177 ±.0245
LOCATION .518

084-088 (8-60)

TECHNICAL ANALYSIS FORM

BY RJ NEIBERT	GENERAL ELECTRIC	PAGE 17/44
CK.		MODEL POD
DATE 11/18/60 REV. 4		REPORT "NMI"

LOCATION CARTRIDGE (CONT)

℄ FWD MOUNT HOLE TO EOP INNER GUIDE 1.5600 ±.0135
INNER GUIDE WIDTH 1.5200 ±.0200
3.0800 ±.0335

℄ FWD MOUNT HOLE TO RIM GUIDE 3.774 ±.007
3.080 ±.0335

RIM TO AFT GUIDE = .694 ±.0405

REF CARTRIDGE 903D830

LOCATIONS =	DIAS =
.518 ±.022	.464 ±.003
.694 ±.0405	.461 ±.003
1.808 ±.058	.3435
2.124 ±.0665	.3080 ±.0005

1.560 CG OF TAPER / .451 ±.003 DIA

1.560 CG
.694 NOM LOCATION
.866

1.560 CG
.518 NOM LOC.
1.042

1 : .012 = .866 : x
.012
.01039
.451
.461392 DIA

1 : .012 = 1.042 : x
.012
.012504
.451
.4635

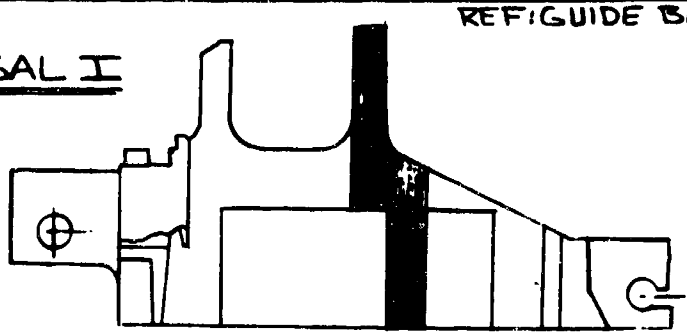
TECHNICAL ANALYSIS FORM

BY R J HEBERT CK. DATE 11/19/68 REV. A	GENERAL ELECTRIC	PAGE 18/44 MODEL GUIDE BAR REPORT "MINI"

DESIGN MODIFICATIONS TO DATE (PROPOSED)

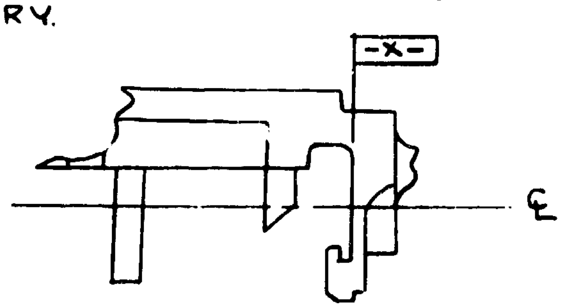
REF: GUIDE BAR 65F9809

PROPOSAL I



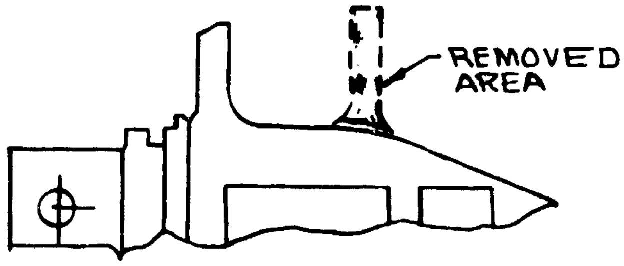
ON FORWARD GUIDE AREA ADD MATERIAL (REF PG 5). THIS WILL COMPENSATE FOR TAPER OF ROUND. THIS ADDITIONAL (SHADED) AREA CAN BE A HARD-FACING PROCESS AND GROUND TO GEOMETRY.

PROPOSAL II



MACHINE GUIDE BAR IMPROVING PERPENDICULARITY OF RIM SEAT (SURFACE X) TO GUIDE BAR ℄. MACHINE TWO PIECES ONE INCORPORATING PROPOSAL I AND ONE PIECE TO EXISTING GEOMETRY.

PROPOSAL III



SUGGEST REMOVAL OF FORWARD GUIDE AS A CORRECTIVE MEASURE, THIS PROJECTION MAY AT PRESENT CONTRIBUTE TO, IF NOT CAUSE MALFUNCTIONS. FURTHER IT IS POSSIBLE THAT THIS GUIDE MAY INDEED NOT CONTACT THE CARTRIDGE (PAGE 5), ANOTHER ADVANTAGE TO REMOVAL, IF THE ABOVE HOLDS TRUE, IS A COST REDUCTION.

664-880 (5-59)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 11/22/68 REV. A	GENERAL ELECTRIC	PAGE 19/44 MODEL DELINKING REPORT "MINI"

LOCATION OF ROUND EXITING FEEDER

\# 2.9025 ± .0025
.0930 ± .0010 FWD GUIDE

2.8095 ± .0035 CARTRIDGE ASSEMBLY
2.7800 ± .0150 CARTRIDGE

.0295 ± .0185

REFERENCE
1. GUIDE, CAM 11701137
2. HOUSING, FEEDER 11686378
3. FWD GUIDE 11701138
4. SPROCKET 11701130

2.8095 ± .0035
1.0530 ± .0010

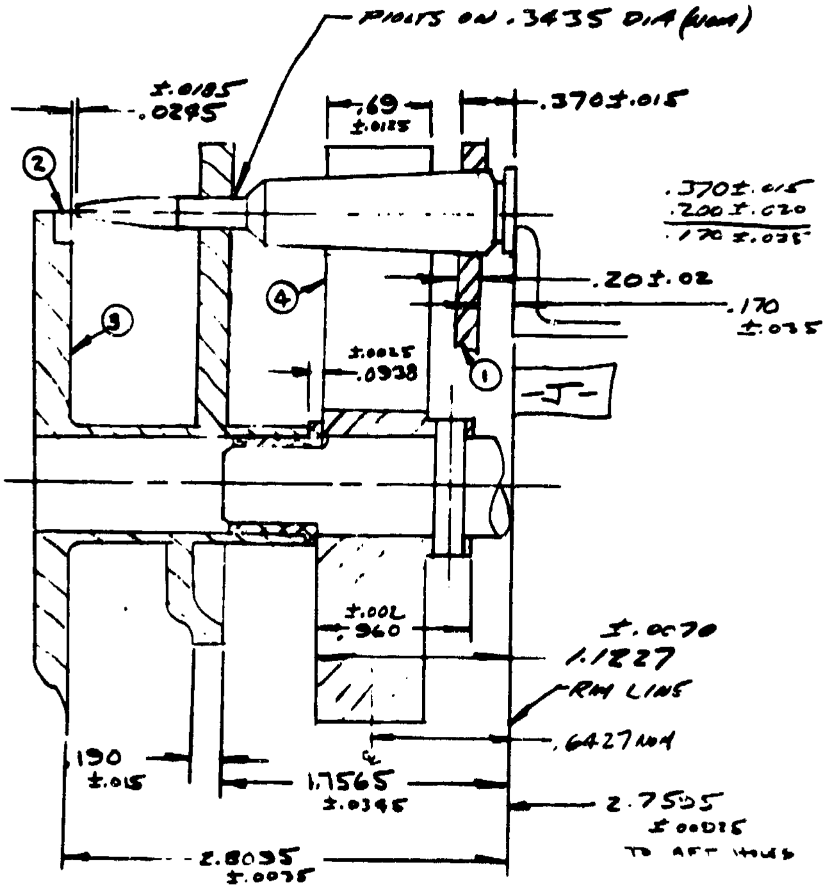
1.7565 ± .0345

1.160 ± .025
.137 ± .016

1.023 ± .041

2.8095 ± .0035
1.6868 ± .0035

1.1227 ± .0070



△1 MACH FACE TO "RIM" EDGE — 1.430 ±.015 CAST
△2 RIM EDGE TO END (FRONT) — .370 ±.015 ...

1.80 ±.03 ...

MAXIMUM ARCHANGE OF ±.005 BETWEEN △1 & △2 THEREFORE RIM IS LOCATED ±.005 FROM HOUSING SHOULDER

FEEDER HOUSING AFT MOUNTING HOLE PATTERN TO FWD EDGE 5.668 B.C [⊕ ±.005] ±.0015 ⊕ FWD B...
FWD EDGE TO RIM GUIDE FACE [J] 2.9025 ±.0025 #
RIM GUIDE TO SHOULDER .0000 ±.0050

2.9025 ±.0075

2.9025 ±.0075
2.7535 ±.010
AFT HOLES TO RIM GUIDE

TECHNICAL ANALYSIS FORM

BY RJHEBERT CK. DATE 11/25/68 REV. A	GENERAL ELECTRIC	PAGE 20/44 MODEL DELINKING REPORT "MINI"

LOCATION OF ROUND (CONT)

(DIA'S FOR LAYOUT)

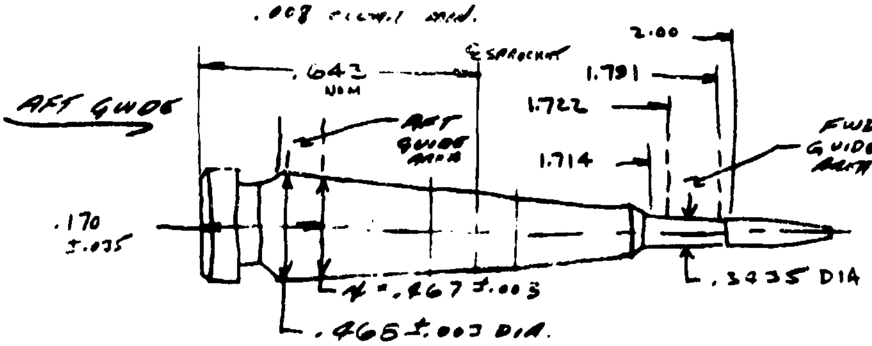
FWD GUIDE — ALWAYS PIVOTS ON .3935 NOM. DIA.

1.7565
−.0345
1.722 MIN LOCATION FORWARD

1.714 END OF ROUND ℄ CANTING
.008 CLEAR. MIN.

1.7565
.0345
1.7910 MAX LOCATION
2.000 MIN LOCATION
(EG OF .3935 DIA)

AFT GUIDE



.170
.035 +
.205

1.560 LG OF TAPER
.205 LOCATION
1.355

1:.012 = 1.355 : ℄
.012
2710
1355
.016260
.451 ±.003 TAPER DIA
℄ = .467 ±.003 DIA

SPROCKET

1.560 LOCATION
.643 LOCATION
.917

1:.012 = .917 : ℄
.012
1834
917
.011004
.451 ±.003
.462 ±.003 DIA

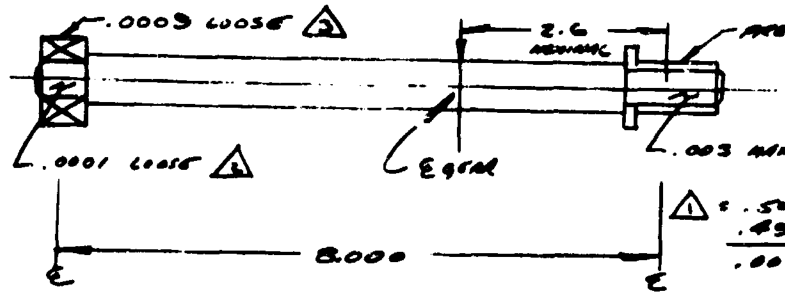
TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 11/25/68 REV. A	GENERAL ELECTRIC	PAGE 21/44 MODEL DELINKING REPORT "MINI"

BACKLASH, DELINKING FEEDER

REFERENCE
SHAFT 1170136
BRG 1170116
BRG 1170115

POSSIBLE RADIAL MOVEMENT SHAFT AT FEED GEAR LOCATION = .0013+



1 = .5020 MAX BORE
.4990 MIN SHAFT
.003 MAX CLEAR

I.D.

8.00 .0031

1 .0030
2 .0001

$8 \overline{)\,.0031}$
.0004 × 2.62 = .001048 4

8.00 .0003

3

8.00 $\overline{)\,.0003}$
.00011 × 2.62 = .000288 5

4 .001048
5 .000288
.001336

POSSIBLE RADIAL MISLOCATION GEAR TO SHAFT = .0030+

REFERENCE
GEAR 1170131
GUIDE 1170135
SHAFT 1170136

FIT I.D. GEAR TO GUIDE MIN GUIDE 1.812 (1.813 − .001)
MAX GEAR 1.814 (1.813 + .001)
±.002 MAX OFFSET
.001 R ⊙ GUIDE TO I.D.
±.003

APT PIN 6381094B $\frac{.1885}{.1870}$ APT PIN HOLE $\frac{.193}{.192}$ = .0035/.006 LOOSE

MAX RADIAL MISLOCATION GUN = .0052 (PAGE 8)
MAX RADIAL MISLOCATION FEEDER = .0030
MAX TOL IN RETAR PIN = .0060
MAX TOTAL .0142

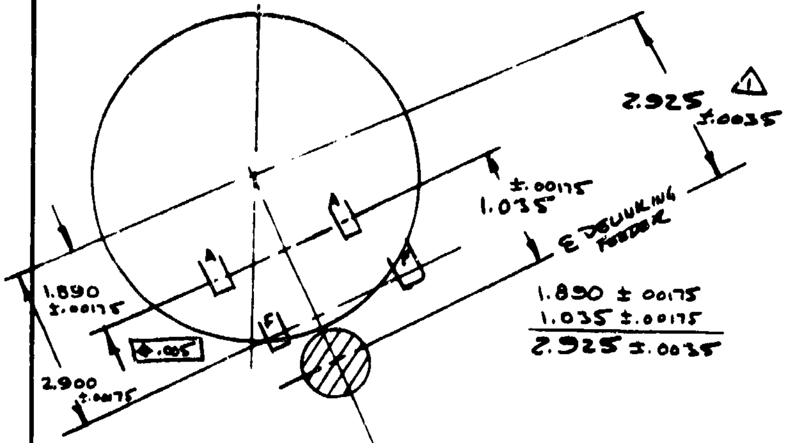
684-080 (8-80)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 11/25/68 REV. A	GENERAL ELECTRIC	PAGE 22/44 MODEL DELINKING REPORT "MINI"

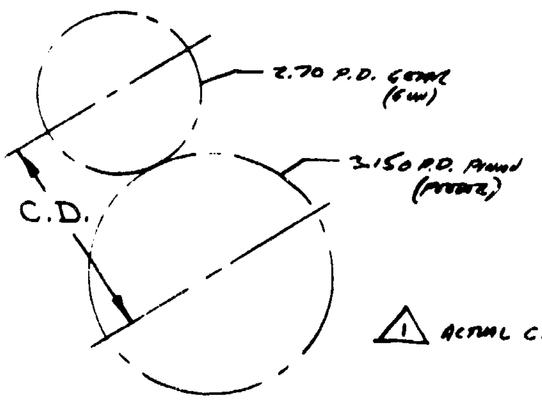
BACKLASH, CONT.

REFERENCE
GUN HOUSING (SEE PG 8)
FEED HOUSING 11686378



1.890 ± .00175
1.035 ± .00175
2.925 ± .0035

CENTER DISTANCE



C.D. = (P.D. PINION + P.D. GEAR + (2 x T.C.E.)) / 2

C.D. = 2.70 + 3.15 + COM. ERROR GEAR .0015, COM. ERROR PINION .0030 = .0045

C.D. = 2.7000
3.1500
.0045
2) 5.8545
2.92725 ULTIMATE DESIGN

⚠1 ACTUAL C.D. OF PARTS 2.9215/2.9285 (±.0035)

2.92725 ULT. DES.
2.92150 MIN. ACTUAL
.00575 INTERFERENCE (MAX)

2.92850 MAX. ACTUAL
2.92725 ULT.
.00125 MAX SEPARATION

⚠2

FROM PAGE 21 WE HAVE DETERMINED MAX RADIAL TOLERANCE = .0142
FROM ⚠2 WE HAVE (−) .00575 INTERFERENCE (+) .00125 SEPARATION
THIS WILL CHANGE OUR C.D. TO .01420 − .00575 (−) = .00845 MIN ; .01420 + .00125 (+) = .01545 MAX

BACKLASH = C.D. CHANGE x (2 x TAN 20° PRESS ∡) = C.D. CHANGE x .72792

BACKLASH MIN .72792 x .00845 = .00615

BACKLASH MAX. .72792 x .01545 = .01125

BACKLASH IN RADIANS (MIN) .00615 / 1.125 x 57.3° = .305°

MIN 0°18'13"

IN RADIANS (MAX) .01125 / 1.125 x 57.3° = .573°

MAX 0°34'22"

684-800 (8-60)

TECHNICAL ANALYSIS FORM

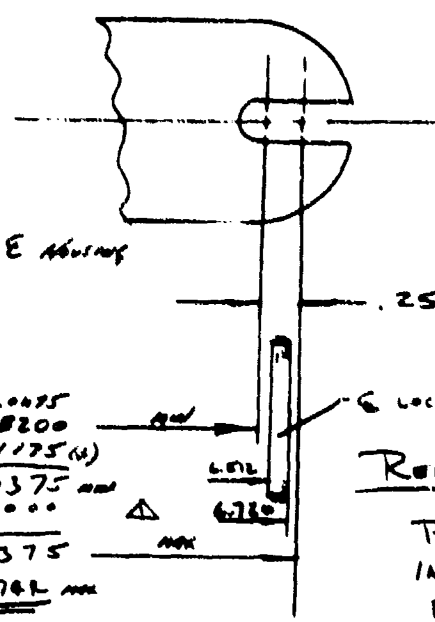
BY R J HEBERT CK. DATE 11/25/68 REV. A	GENERAL ELECTRIC	PAGE 83/44 MODEL DELINKING REPORT "MINI"

ASSY OF FEEDER TO HOUSING (GUN)

[illegible]
[illegible] 5.0[illegible]
[illegible] 5.0[illegible]
[illegible] .840
.005/.010 — 6.5120
[illegible] — 5.0035

PLATE, FWD GUIDE 11701138
℄ FWD MOUNT SLOT TO BACK ANGLE [-B-]
HOUSING FEEDER 11686378 [⊕ .005]

.820 ± [illegible]
5.662 ± [illegible]
6.482 ± .01175 ℄ to ℄ MOUNT



6.512 NOMINAL ℄ TO ℄ HOUSING

.25 MIN LG OF .191 [illegible] ⚠
+.003

℄ LOCATION OF PIN

5.0035
6.48200 MIN
.01175 (+)
6.49375 MIN
.25000 ⚠
6.74375 MAX
6.742 MAX

6.512
6.720

RESULT

PIN ALWAYS FALLS IN TOL. ZONE OF FEEDER SLOT

6.48200
.01175 (−)
6.47025
.250
6.720

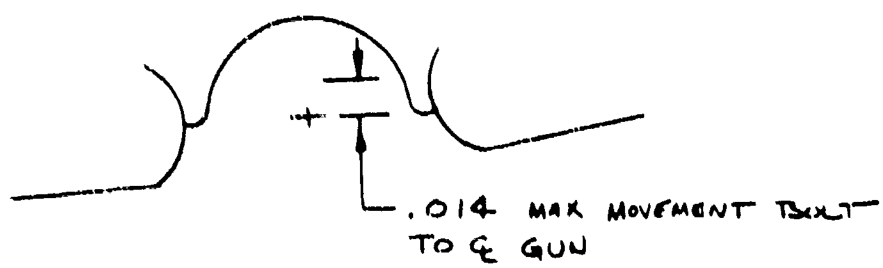
664-658 (6-60)

TECHNICAL ANALYSIS FORM

BY [illegible] CK. DATE [illegible] REV. A	GENERAL ELECTRIC	PAGE [illegible]/44 MODEL [illegible] REPORT [illegible]
[illegible]		

Backlash *

[illegible]	[illegible]	[illegible]
[illegible]	0°3[illegible]'[illegible]5"	0°[illegible]5'[illegible]"
A 37	([illegible]	[illegible])
[illegible]D	0°55'0"	1°25'3[illegible]"
[illegible]	0°18'19"	0°3[illegible]'22"



* BACKLASH IS AMMOUNT OF ANGULAR MOVEMENT OF THE FEEDER SPROCKET FROM ITS TIMED POSITION.

064-900 (8-84)

TECHNICAL ANALYSIS FORM

BY CK. DATE 11/68 REV. A	GENERAL ELECTRIC	PAGE 25/44 MODEL MODULE REPORT "MINI"

CALCULATION TO ~~DETERMINE~~ ∡ OF TWIST IN ~~FEEDER~~ SHAFT

$$\theta = \frac{TL}{GJ}$$

T = TORQUE ON THE SHAFT
MAX TORQUE ON MODULE FEEDER SHAFT WAS FOUND TO BE APPROX. 40 IN-LB

L = LENGTH
LENGTH OF SHAFT IS APPROX 6.0 INCHES

G = MODULUS OF ELACTICITY
M OF E IS 10.2×10^6 PSI (STEEL TYPE 300)

$$J = \frac{\pi}{32}(D^4) \qquad D = .5 \text{ INCHES}$$

$$J = \frac{\pi}{32}(.5)^4 = 6.136 \times 10^{-3}$$

$$\theta = \frac{(40 \text{ IN-LB})(6 \text{ INCHES})}{(10.2 \times 10^6 \frac{LB}{IN^2})(6.136 \times 10^{-3})} = 3.8346 \times 10^{-3}$$

$$\theta = .0038346 \times \frac{180}{\pi} = .219664°$$

$$\theta = 13.17984'$$

POSSIBLE ∡ DEFLECTION

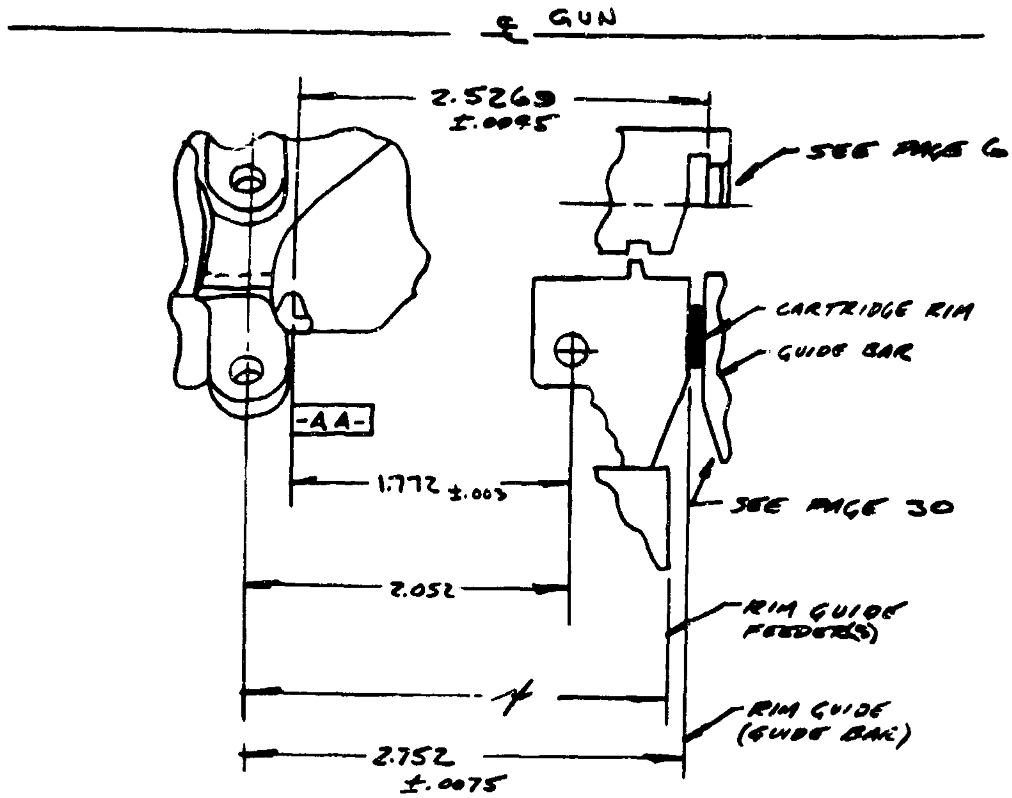
004-000 (0-00)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 12/3/68 REV.	GENERAL ELECTRIC	PAGE 26/44 MODEL REPORT "MINI"

RIM LOCATION FEEDER / GUIDE BAR

DIMENSIONAL ANALYSIS FOLLOWS ON PAGES 26 TO 29 *



FEEDER	✗ *
MODULE	2.752 ±.0055
A-37	2.752 ±.0055
POD	2.738 ±.0125
DELINKING	2.7595 ±.0130

RESULT

ALL FEEDERS GUIDE ROUND RIM INTO BAR WITH NO INTERFERENCE EXCEPT AS SHOWN ON PAGE 30

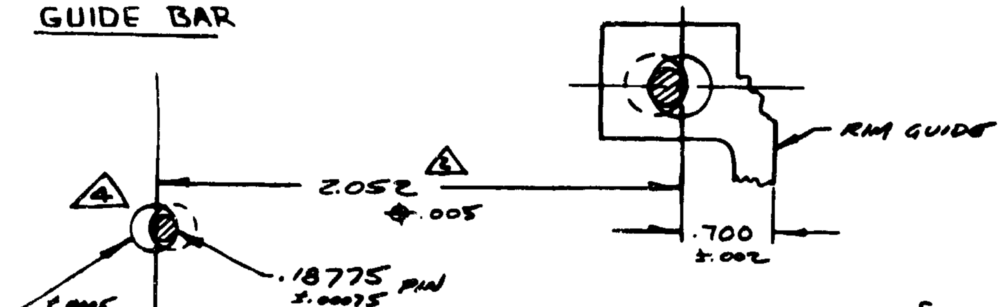
664-880 (8-60)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 12/3/68 REV. A	GENERAL ELECTRIC	PAGE 27/44 MODEL REPORT "MINI"

SEE PAGE 26

GUIDE BAR



LOCATION RIM GUIDE ON BAR ℄ MOUNT

1	.700	±.0020	
2	2.052	±.0025	(TP AXIAL)
3	"FLOAT"	±.0030	
LOCATION = 7	2.752	±.0075	2.7595 / 2.7445

3 = GUIDE BAR .250 .251
HOUSING .250 .252
SCREW .246 .249

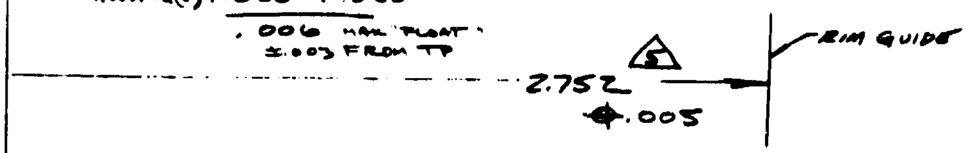
.006 MAX (FLOAT) ±.003 FROM TP

MODULE ℄ A-37

LOCATION RIM GUIDE

4 PIN .1870 .1885
HOUSING(S) .1920 .1930

.006 MAX "FLOAT" ±.003 FROM TP



5	2.752	±.0025	(TP AXIAL)
4	"FLOAT"	±.0030	
LOCATION = 6	2.752	±.0055	2.7575 / 2.7465

RESULT

BAR MAX 2.7595 7
FEED MIN 2.7465 6
.0130 VARIATION

NO INTERFERENCE (BAR HAS .045 MIN CHFS TO ACCEPT CARTRIDGE)

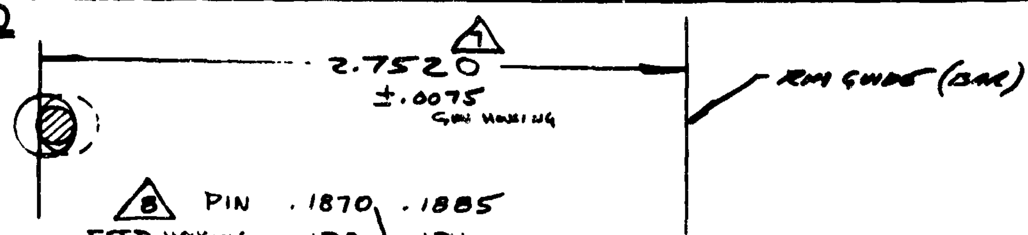
024-000 (0-00)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 12/3/60 REV. A	GENERAL ELECTRIC	PAGE 28/44 MODEL REPORT "MINI"

SEE PAGE 26

POD



8	PIN	.1870	.1885
	FEED HOUSING	.150	.151
	GUN HOUSING	.152	.153
		.006 MAX ("FLOAT")	
		±.003 FROM TP	

FWD ℄ TO INSIDE RIM SURFACE	3.849 ±.005
RIM GUIDE WIDTH	.075 ±.002
FWD ℄ TO RIM GUIDE	3.774 ±.007 (9)

℄ TO ℄ MOUNTING HOLES 6.512 ±.0025 (⊕ .005 AXIAL)

(9) 3.774 ±.0070

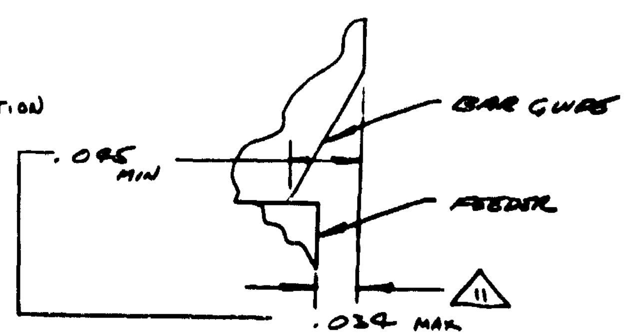
(8) "FLOAT" ±.0030

LOCATION = (10) 2.738 ±.0125 2.7505 / 2.7255

(7) 2.752 ±.0075

(10) 2.738 ±.0125

(11) .014 ±.020 VARIATION



RESULT

NO INTERFERENCE

064-580 (8-60)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT	GENERAL ELECTRIC	PAGE 23/44
CK.		MODEL
DATE 12/3/68 REV. A		REPORT "MINI"

SEE PAGE 26

DELINKING

△7 2.7520 ±.0075 GUN HOUSING

RIM GUIDE (EAR)

△12 PIN .1870 .1885

HOUSING(S) .192 .193

.006 MAX (FLOAT)

±.003 FROM TP

(⌖ .005 MIN)

FEEDER HOUSING AFT MOUNTING HOLES TO FWD EDGE 5.662 ±.0025

FWD EDGE TO RIM GUIDE FACE 2.9025 ±.0025

RIM GUIDE TO SHOULDER .0000 ±.0050

2.9025 ±.0075 → 2.9025 ±.0075

△13 2.7595 ±.0100

△13 A.T HOLES TO RIM GUIDE 2.7595 ±.010

"FLOAT" ±.003

LOCATION = 2.7595 ±.013 △14

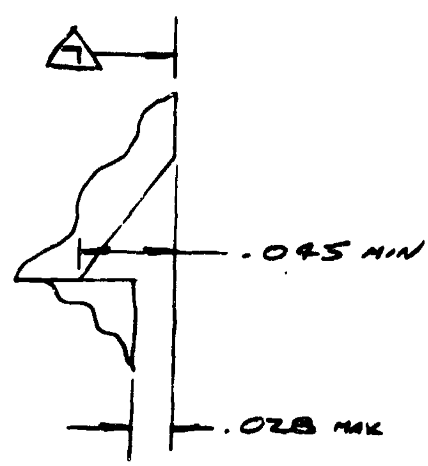
△14 2.7595 ±.0130

△7 2.7520 ±.0075

△15 .0075 ±.0205

.0205

.028 MAX



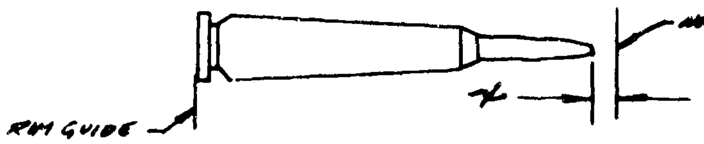
RESULT NO INTERFERENCE

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 12-3-68 REV. A	GENERAL ● ELECTRIC	PAGE 30/44 MODEL POD/DELINK. REPORT "MINI"

STUDY TO DETERMINE AXIAL MOTION OF CARTRIDGE IN FEEDERS

(THIS STUDY WILL NOT APPLY TO MOD 4 A-37 FEEDERS AS FWD SPROCKET ALWAYS APPLYS REAR THRUST ON CARTRIDGE (PAGES 1 & 2)

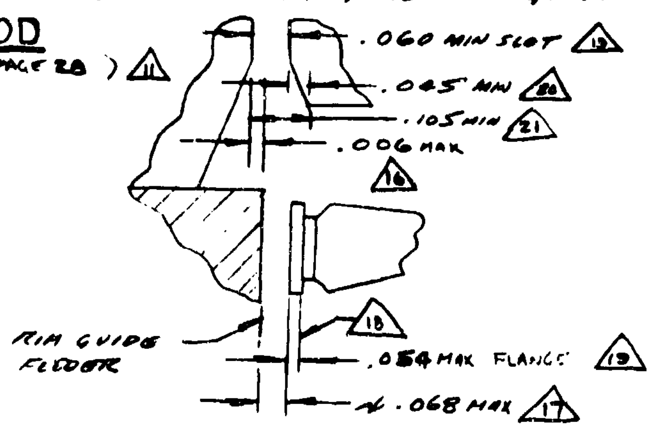


POD ∠ = .068/.007

DELINKING ∠ = .043/.006

STUDY ON PAGE 26 HAS DETERMINED THAT RIM OF ROUND WILL ALWAYS ACCEPT 4° CHF ON RIM GUIDE OF THE BAR. WE SHALL NOW SEE IF FORWARD MOVEMENT OF ROUND (DUE TO DIM ∠) COULD CAUSE INTERFERENCE WITH FWD LIP GUIDE SURFACE (14° ∡)

POD
(REF PAGE 28) 11



11 .014 ± .020   .014
  − .020
16   .006

17 .065 (MAX ∠)
16 .006
19 .054
18 .128
MAX MOVEMENT FWD

21 .105 MIN START OF 14 ∡
18 .128 MAX MOVEMENT CART.

RESULT LIP 18 OF ROUND TO EDGE OF GUIDE BAR CAN HAVE — .023 INTERFERENCE
(CAUSING ROUND TO DELAY)

DELINKING
(REF PAGE 29)

15 = .0075 NOM
− .0205 (− TOL)
.013 16

17 .043 (MAX ∠)
16 .013
19 .054
18 .110
MAX MOVEMENT FWD

RESULT
LIP 18 OF ROUND TO EDGE OF GUIDE BAR CAN HAVE
(CAUSING ROUND TO DELAY)

21 .105 MIN START OF 14 ∡
.110 MAX MOVEMENT AND
.005 INTERFERENCE

004-030 (8-60)

TECHNICAL ANALYSIS FORM

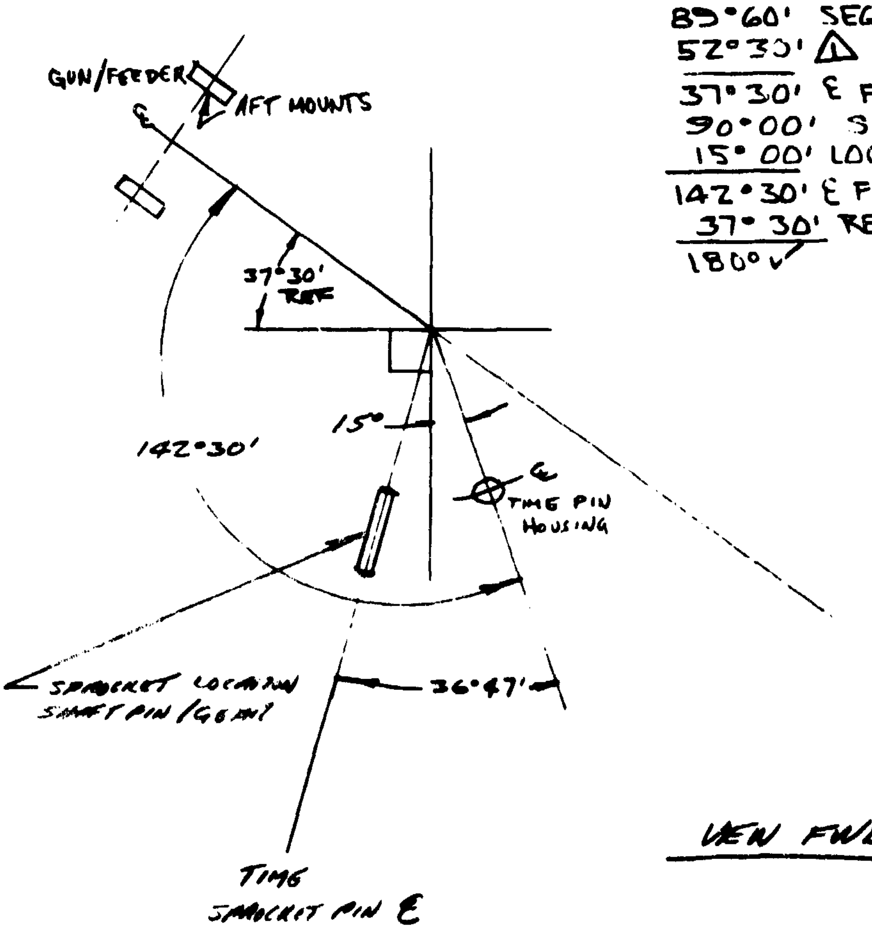
BY RJ HEBERT CK. DATE 12/5/68 REV. A	GENERAL ELECTRIC	PAGE 31/44 MODEL DELINKING REPORT "MINI"

DELINKING FEED, INDEXING OF

REF
FEEDER HOUSING 11686378
GEAR 11701131
SPROCKET 11701130

93°30' ℄ FEED TO MOUNT HOLE
41°00' MOUNT HOLE TO VERT ℄
52°30' VERT ℄ TO ℄ FEED ⚠1

89°60' SEGMENT (90°)
52°30' ⚠1
37°30' ℄ FEED TO ℄ PART
90°00' SEGMENT
15°00' LOC. TIME PIN/VER.
142°30' ℄ FEED/℄ TIME PIN
37°30' REF CHECK
180°✓



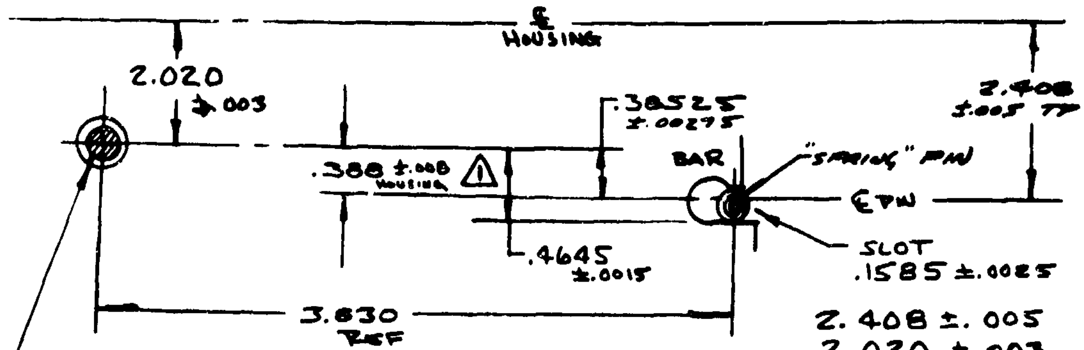
VIEW FWD

004-000 (8-60)

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 12/10/68 REV. A	GENERAL ELECTRIC	PAGE 32/44 MODEL REPORT "MINI"

LOCATION OF GUIDE BAR, "TIPPED" CONDITION



.2510 ±.0010 HOUSING
.2505 ±.0005 BAR
.2475 ±.0015 BOLT (SCR)
"FLOATS" ±.003

2.408 ±.005
2.020 ±.003
HOUSING .388 ±.008

⚠1 .38800 ±.008
.38525 ±.00275
"FLOATS" ±.003
.00275 ±.01375 PIN TO SCREW DIFFERENCE

⚠2 $\frac{.01650}{3.825\ \text{MIN}} = .00431 = \measuredangle\ 15'$ MAX

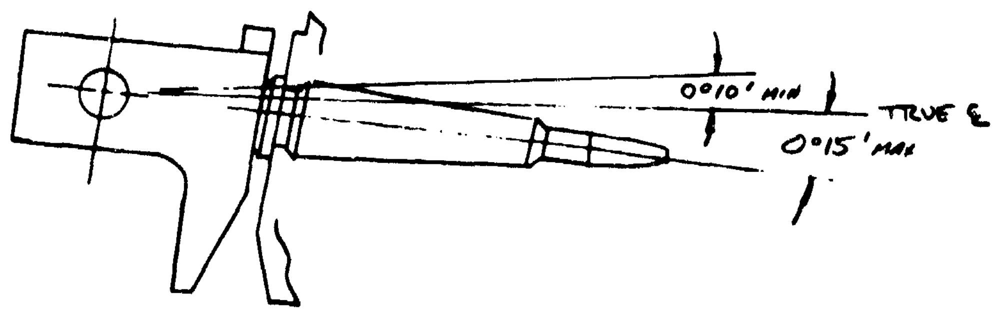
$\frac{.011}{3.825} = .0028 = \measuredangle\ 10'$ MIN

.00275
.01375 (+)
⚠2 .01650 MAX

.01375
.00275 (−)
.011 MIN ⚠3

Result

GUIDE BAR COULD "TIP" CARTRIDGE AS SHOWN BELOW



HOWEVER MISALIGNMENT WILL NOT EXIST AS THIS DOES NOT EXCEED THE LIMITS ON PAGE 7

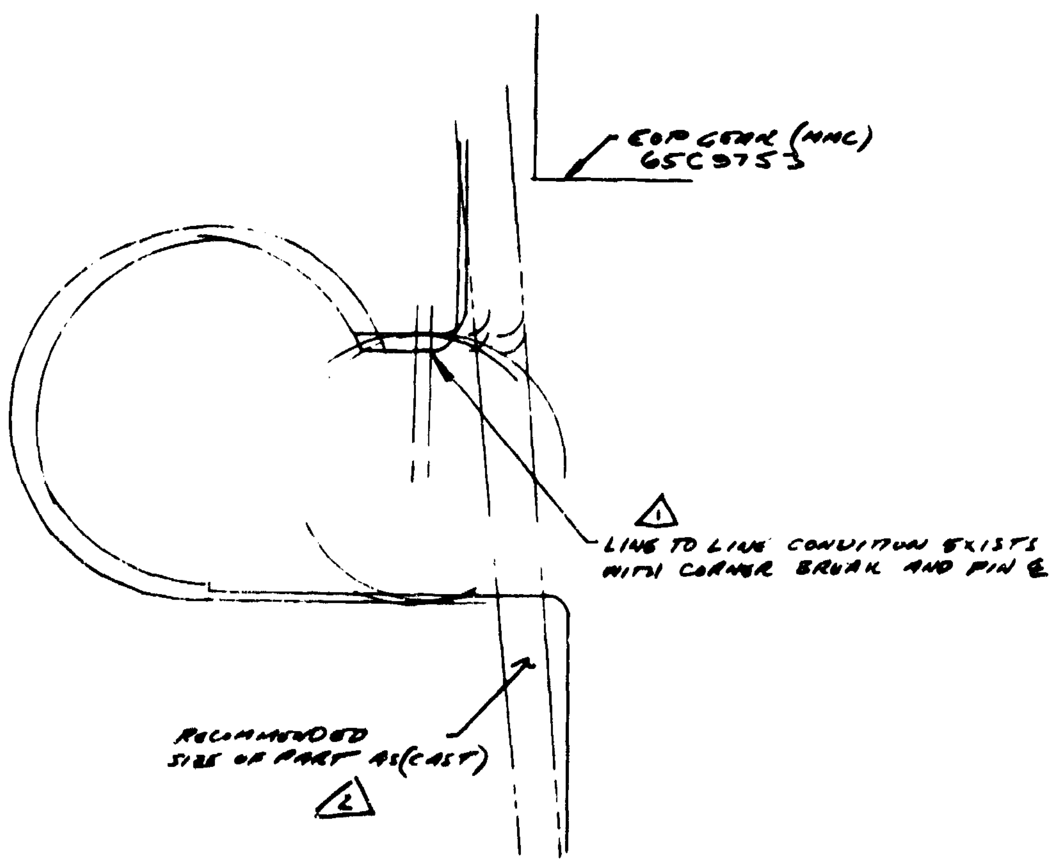
064-050 (8-66)

TECHNICAL ANALYSIS FORM

BY R J HERBERT CK. DATE 12/12/60 REV.	GENERAL ELECTRIC	PAGE 33/44 MODEL REPORT "MINI"

GUIDE BAR, ROTATION OF

RESULT OF STUDY SHOWS THAT △1 EXISTS. TO ALLOW FOR POSITIVE LOCATION RECOMMEND INCREASING CONTACT AREA OF PIN, POSSIBLE TO OBTAIN THIS BY AN AS CAST CONDITION AS SHOWN △2



REFERENCE
LAYOUT 10X
[illegible] 12/11/60

664-880 (8-60)

TECHNICAL ANALYSIS FORM

BY R J HEBERT CK. DATE 12/31/68 REV. A	GENERAL ELECTRIC MAU 100/B (MODULE) MAU 57 A/A (POD) MAU 58/B (A-37) MAU 56/A (DELINKING)	PAGE 34/44 MODEL ALL REPORT "MINI"

MINIGUN GUIDE BAR STUDY, SUMMARY AS OF DATE

DESIGN STUDY CONSISTED OF GUIDE BAR RELATIONSHIP TO GUN HOUSING AND MAU 100/B, MAU 58/B, MAU 57 A/A AND MAU 56/A FEEDER SYSTEMS.

FEED SYSTEMS

ILLUSTRATED THAT CARTRIDGE MAY NOT ALWAYS ENTER BOLT PARALLEL TO CENTERLINE OF GUN BY ∡ 0°31' MAX (INBD/OUTBD) DUE TO TOLERANCES OF FEED SPROCKETS MAU 100/B, MAU 58/B AND MAU 57 A/A. DELINKING SPROCKET IS OF A DESIGN THAT DOES NOT INTRODUCE ANGULARITY TO ROUND. (NOTE PAGES 1 AND 2) ALSO ON MAU 100/B AND MAU 58/B AN AFT AXIAL FORCE IS EXERTED ON CARTRIDGE PROVIDING POSITIVE CONTROL. ON MAU 57A/A AND MAU 56/A FEEDERS, CARTRIDGE IS NOT CONTROLLED BY THIS FEATURE, AND IS ALLOWED TO "FLOAT" IN IT'S FEED GUIDES BEFORE ENTERING GUIDE BAR. DUE TO THIS NEGATIVE CONTROL AND A TOLERANCE BUILD-UP IN MAU 57A/A AND MAU 56/A FEEDERS (NOTE PAGE 30) INTERFERENCE OF THE CARTRIDGE MAY OCCUR AT GUIDE BAR CONTACT RESULTING IN DELAY OF FEED AND POSSIBLE MALFUNCTION.
CORRECTION FACTOR HERE WOULD BE TO INCREASE ∡ OF GUIDE BAR ENTRANCE FROM .045 +.020 × 14° TO .068 +.020 × 14°

BACKLASH

OCCURS IN ALL SYSTEMS FROM 0°18'19" MINIMUM IN MAU 56/A TO A MAXIMUM OF 1°25'38" IN MAU 57A/A.
CORRECTION FACTOR MAY BE TO IMPROVE GEAR TOLERANCES AND IN THE CASE OF MAU 57A/A ELIMINATE SPLINED TWO-PIECE SPROCKET AS THIS GREATLY INCREASES BACKLASH AND IS A CAUSE OF UNCONTROLLED CARTRIDGE HANDLING IN THIS SYSTEM.

TIMING

ALL SYSTEMS ARE EARLY FED RESULTING IN A POSITIVE (INTERFERENCE) CONTROL OF CARTRIDGE HANDLING IN GUIDE BAR. THIS VARIES IN THE FEED CYCLE FROM A MINIMUM "CRIMPING" OF .008 ON MAU 56/A (NOTE PAGES 3) TO A MAXIMUM OF .053 ON MAU 100/B, MAU 58/B AND MAU 57A/A. THIS MAY BE EXCESSIVE INTERFERENCE AND CORRECTIVE MEASURES COULD BE A VARIABLE ARC LENGTH IN GUIDE BAR TO A VARIABLE FEEDER SHAFT.

004-000 (0-00)

TECHNICAL ANALYSIS FORM

BY R J HERBERT CK. DATE 12/31/68 REV. A	GENERAL ELECTRIC	PAGE 34A/44 MODEL ALL REPORT "MINI"

SUMMARY, CONT.

GUIDE BAR GEOMETRY

A LINE TO LINE CONDITION EXISTS (SEE PAGE 33) ON GUIDE BAR / PIN LOCATION. IT WOULD BE ADVISABLE TO MINIMIZE THE AREA OF CONTACT DUE TO MANUFACTURING AND ASSEMBLY MISMATCH. [illegible] THE END OF THE GUIDE BAR COULD BE LENGTHENED AND KEPT WITHOUT MACHINING BY INCORPORATION OF AN ANGULAR SURFACE.

ANOTHER AREA OF CONSIDERATION MAY BE [illegible] OF CARTRIDGE AFTER ENTERING GUIDE BAR. (SEE PAGE 5) DUE TO AN [illegible] OF TAPERED GEOMETRY ON CARTRIDGE THE GUIDE BAR MAY ROTATE THE CARTRIDGE TO THE INBOARD (TOWARDS ℄ OF GUN) BY 0°30'. THIS CAN BE OVERCOME BY ADDITION OF MATERIAL ON FORWARD AREA OF GUIDE BAR.

024-000 (8-89)

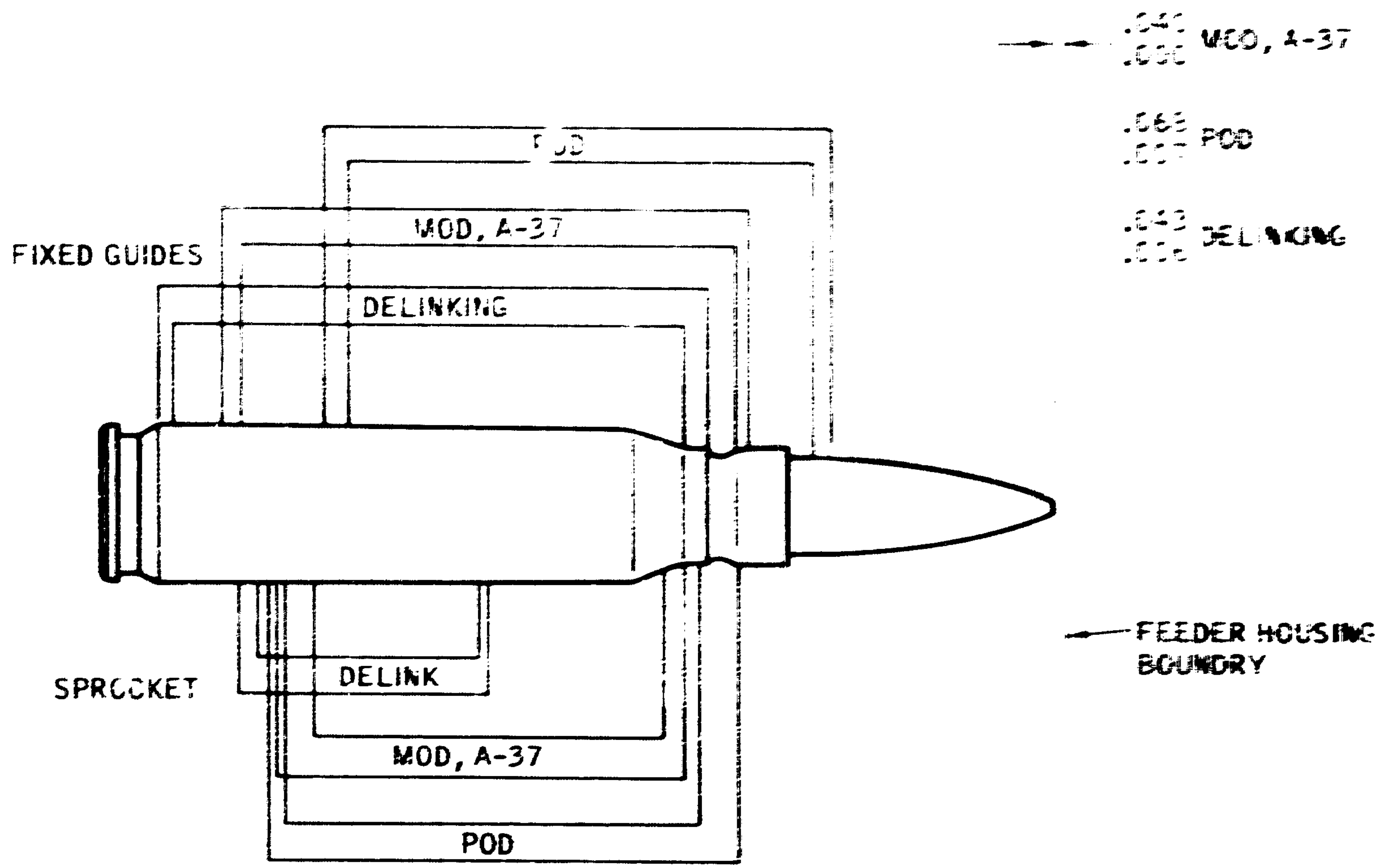


Figure 105. Maximum-Minimum Positions of Feeder Components

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 12/31/68 REV.	GENERAL ELECTRIC	PAGE 34/44 MODEL REPORT "MINI"

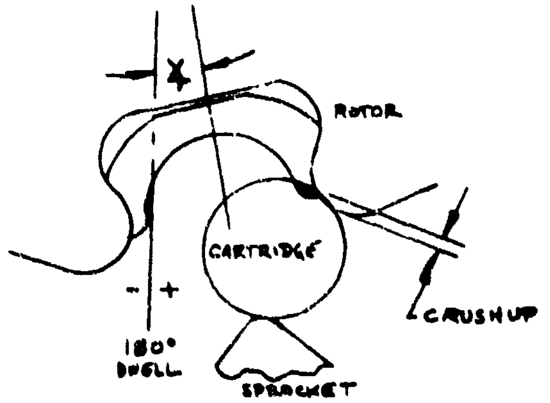
CRUSH-UP VALUES

THIS INCLUDES BOLT MOVEMENT AWAY FROM ROUND PATH, DEVIATION OF FEEDER CENTER DISTANCE AND BACKLASH.

	MAU 100/B AND MAU 58/B		MAU 57 A/A	
X	MINIMUM **	MAXIMUM *	MINIMUM **	* MAXIMUM
-5.0	.000	.008	.000	SAME AS MAU 100/B + MAU 58/B
-2.5	.000	.035	.000	
0	.005/.008	.040	.000 .005	
+2.5	.006/.012	.044	.000 .006	
5.0	.009/.016	.055	.003 .012	
7.5	.006/.010	.060	.005 .015	
10.0	.005/.007	.066	.000 .002	
12.5	.004/.006	.070	.000	
15.0	.002/.005	.080	.000	
17.5	.002/.005	.082	.000	
20.0	.008/.010	.060	.000	
22.5	.009/.012	.035	.000	
CARTRIDGE SEATED STARTS TO TRANSLATE OUT OF DWELL				
25.0	LINE TO LINE	.039	LINE TO LINE	
27.5	LINE TO LINE	.042	LINE TO LINE	
30.0	LINE TO LINE	.037	LINE TO LINE	
32.5	LINE TO LINE	.027	CART. LEAVES CONTACT WITH SPROCKET	
35.0	CART. LEAVES CONTACT WITH SPROCKET	.020		
37.5		CART. LEAVES CONTACT WITH SPROCKET		

* BACKLASH = 0

** BACKLASH = MIN/MAX



[illegible]

TECHNICAL ANALYSIS FORM

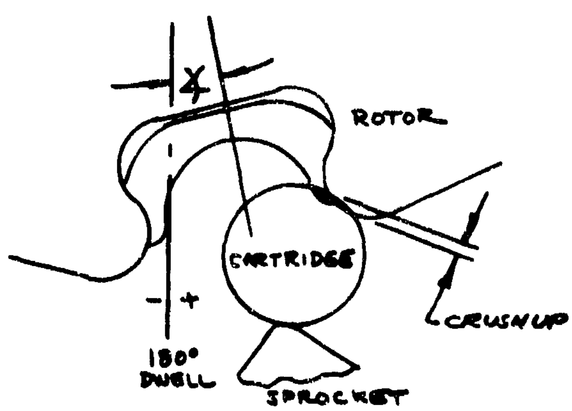
BY RJ HEBERT CK. DATE 12/31/68 REV.	GENERAL ELECTRIC	PAGE 364/44 MODEL REPORT "MINI"

CRUSH-UP VALUES, CONT

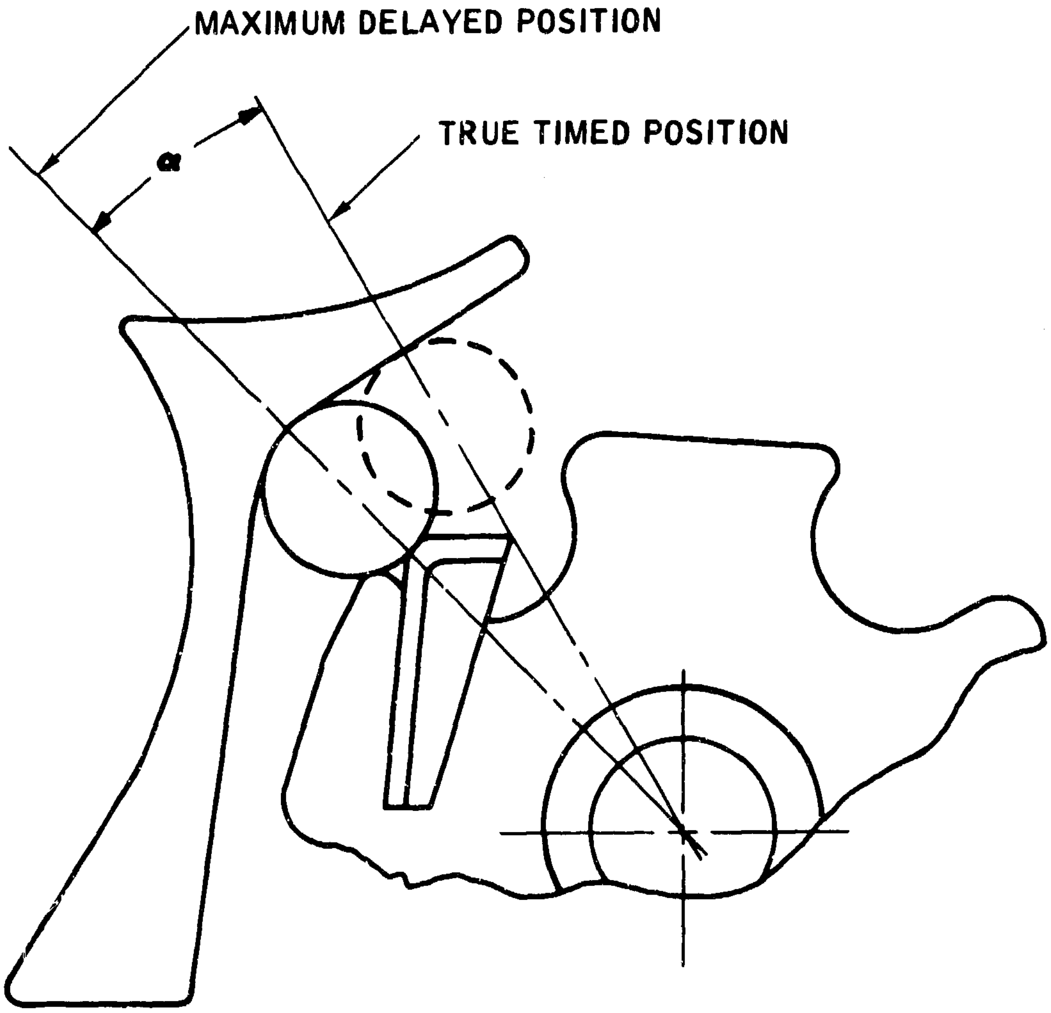
MAU-56A

∡	MINIMUM **	MAXIMUM *
-5.0	.000	.000
-2.5	.000	.009
0	.003/.008	.028
+2.5	.004/.008	.040
5.0	.008/.012	.045
7.5	.008/.013	.048
10.0	.005/.010	.060
12.5	.003/.009	.066
15.0	.004/.010	.068
17.5	.009/.012	.070
20.0	.003/.009	.065
22.5	CARTRIDGE SEATED STARTS TO TRANSLATE OUT OF DWELL	
25.0	.007/.009	.033
27.5	.010/.012	.030
30.0	.010/.012	.030
32.5	.008/.010	.025
35.0	CART. LEAVES CONTACT WITH SPROCKET	.018
37.5		CART. LEAVES CONTACT WITH SPROCKET

* BACKLASH = 0
** BACKLASH = MIN/MAX



664-850 (6-60)



FEED SYSTEM	α
MODULE	5°
A - 37	5°
POD	5°
DELINKING	$3\ 1/2^{\circ}$

Figure 106. Maximum Allowable Delay to Feeder Sprocket from Timed Position

TECHNICAL ANALYSIS FORM

BY R J HEBERT CK. DATE 1-7-69 REV.	GENERAL ELECTRIC	PAGE 37/44 MODEL [illegible] REPORT "MINI"

CARTRIDGE VELOCITY (TANGENTIAL & RESULTANT)

$V = \omega R$

$\omega = (1200)(RPM)$

$\omega = (20)(RPS)$ 2π RADIANS

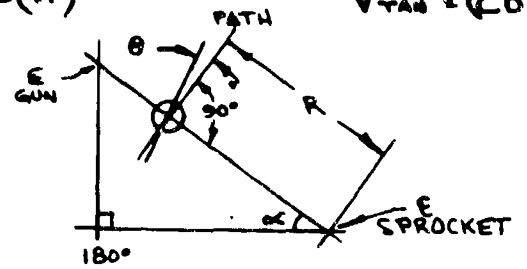
$V = 40(\pi)$

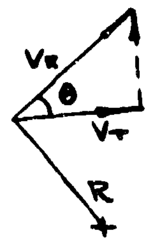
$V_{TAN} = (40\pi)(R)$

$V_{TAN} = (126)(R) =$ IN/SEC

$V_{RESULTANT} = \dfrac{V_{TAN}}{\cos\theta} =$ IN/SEC

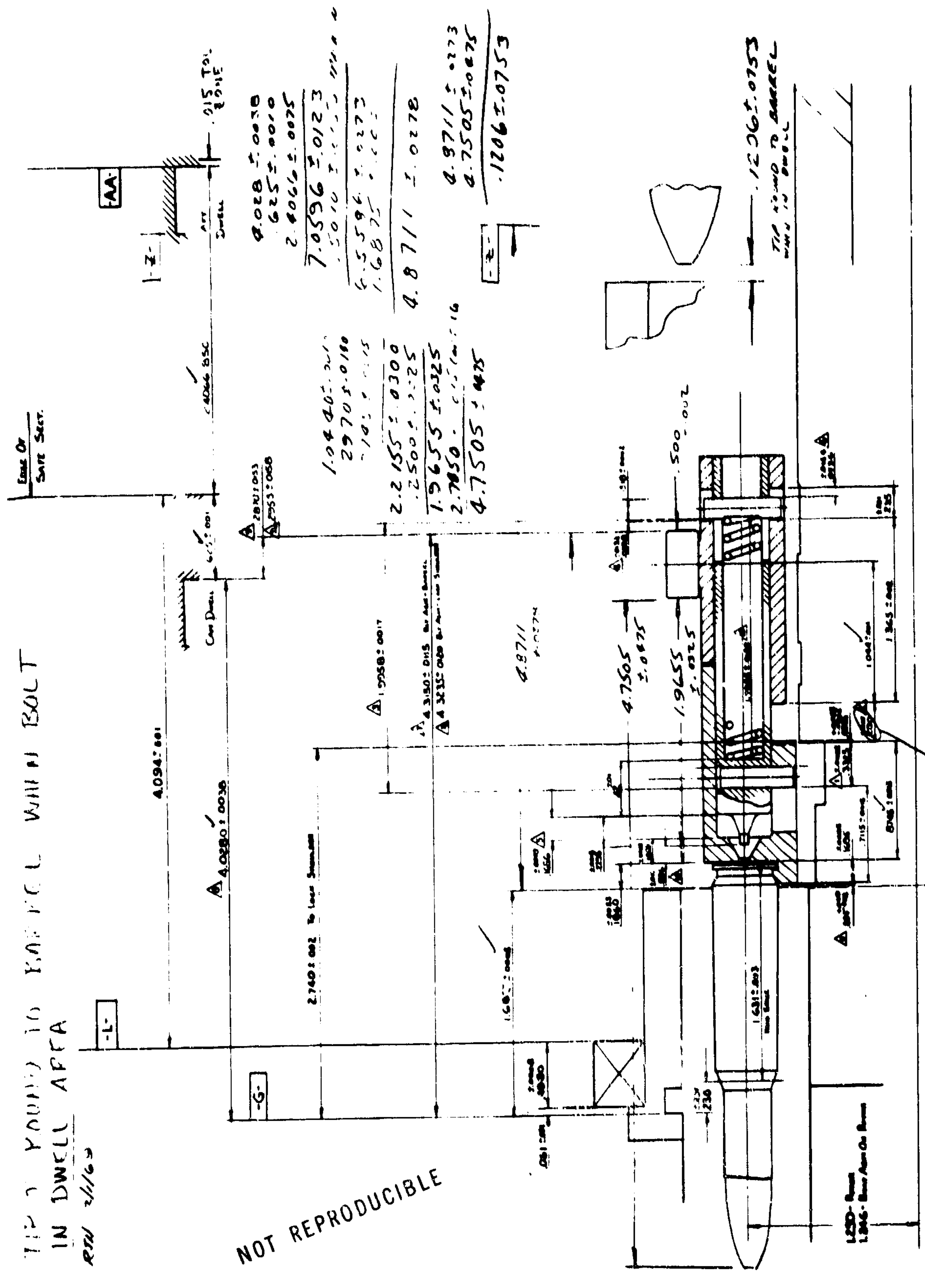
$V_{TAN} = (\cos\theta)(V_{RESULTANT})$

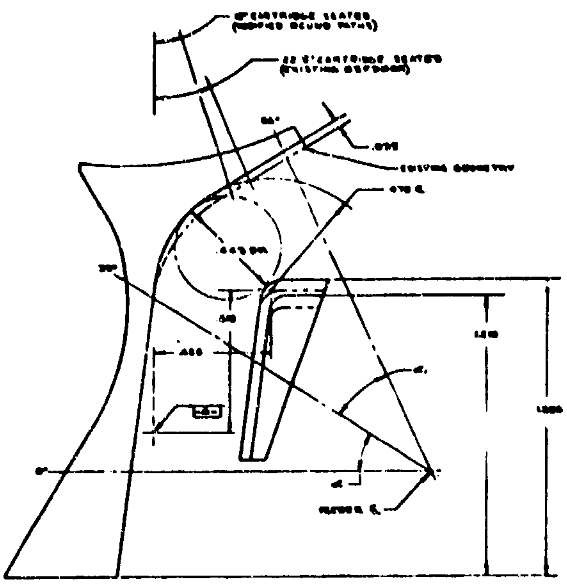




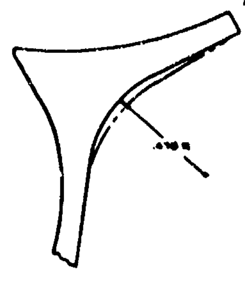
α	θ	R	VT IN/SEC	VR IN/SEC	
0°	7	.990	124	125	
3	6	.988	124	125	
6	1½	.988	124	124	
9	2½	.987	124	124	
12	5	.990	124	124	
15	8	.996	125	126	
18	10¼	1.005	127	129	
21	12½	1.017	128	131	
24	17	1.029	130	136	
27	24	1.072	135	148	
30	24	1.092	135	148	
33	25	1.121	141	156	
36	29½	1.130	142	176	CONTACT WITH BOLT
39	18¾	1.160	146	188	
42	14	1.189	150	202	
45	5½	1.205	152	153	
48	0	1.212	153	153	
51	8	1.216	153	154	
54	5½	1.215	153	153	
57	1½	1.210	152	152	
60	1	1.210	152	152	
63	5	1.216	153	153	CARTRIDGE SEATED
66	8	1.221	154	155	

034-899 (8-60)

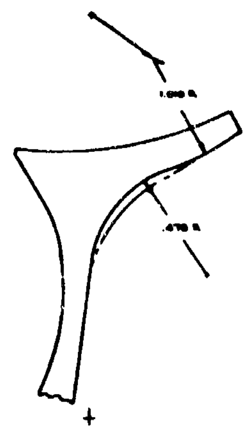

TIP OF ROUND TO BARREL WHEN BOLT
IN DWELL AREA
RSN 2/1/63



PROPOSAL I
(GEOMETRY SAME AS EXISTING EXCEPT AS SHOWN)



PROPOSAL III
(GEOMETRY SAME AS II EXCEPT AS SHOWN)



PROPOSAL II
(GEOMETRY SAME AS I EXCEPT AS SHOWN)

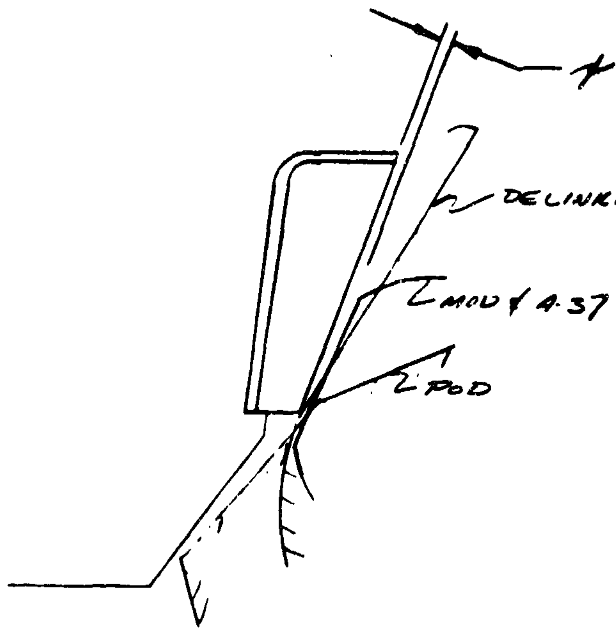
[illegible]

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 2/7/69 REV.	GENERAL ELECTRIC	PAGE 40/44 MODEL REPORT 'MINI'

RIM GUIDE RELATIONSHIP TO FEEDERS

10X LAYOUT MADE TO DETERMINE CLEARANCES BETWEEN FEEDERS AND GUIDE BAR SURFACES.



RESULTS

ALL FEEDERS HAVE SUFFICIENT CLEARANCE WITH GUIDE BAR. REFERENCE LAYOUT FOR ACTUAL GEOMETRY.

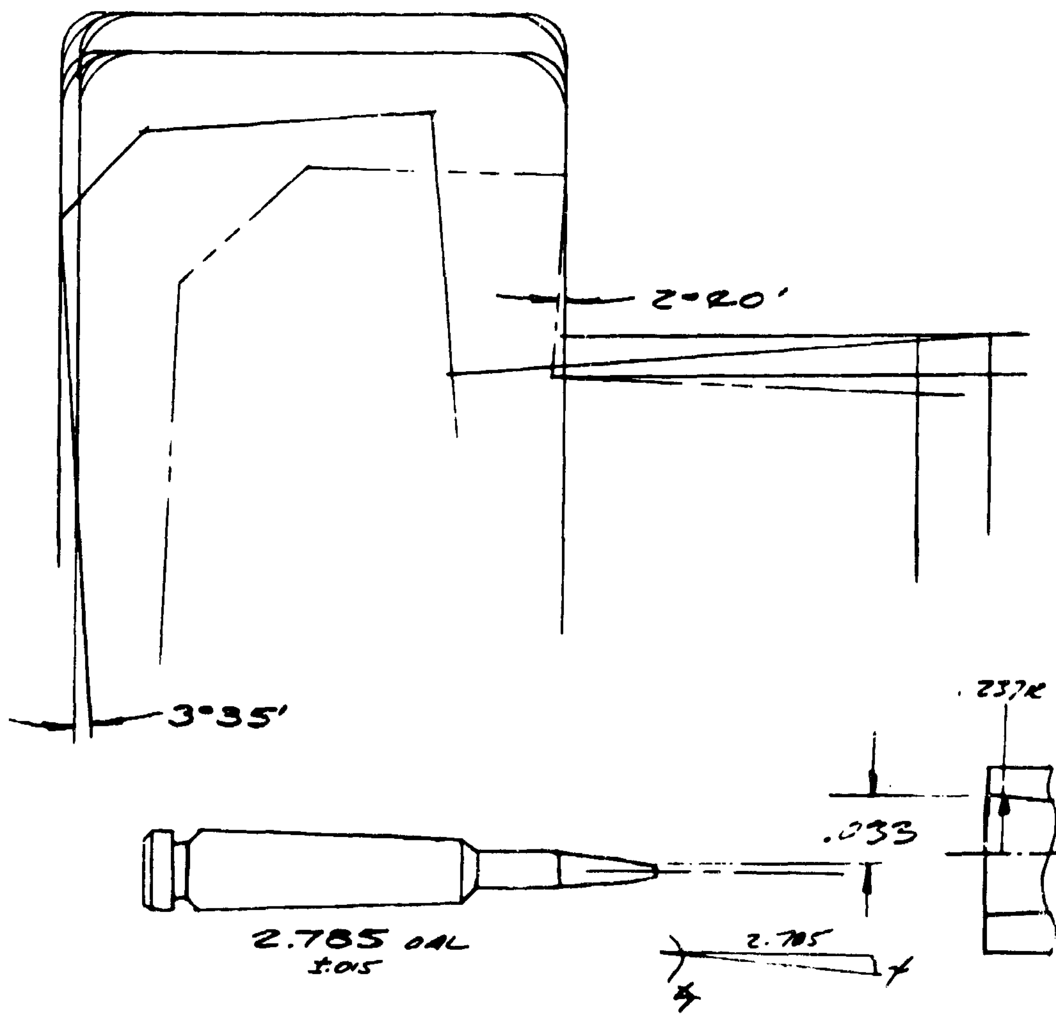
$\nvdash$ (MIN CLEARANCE)	FEEDER
.014	MOD ¥ A-37
.016	POD
LINE TO LINE	DELINKING

064-000 (0-00)

TECHNICAL ANALYSIS FORM

BY R J HEBERT CK. DATE 2/13/69 REV.	GENERAL ELECTRIC	PAGE 41/44 MODEL REPORT "MINI"

ROUND MOVEMENT IN EXTRACTOR LIP / BARREL



MAX ∤ = TAN 3°55' × .06262
MAX ∤ = .172 Δ

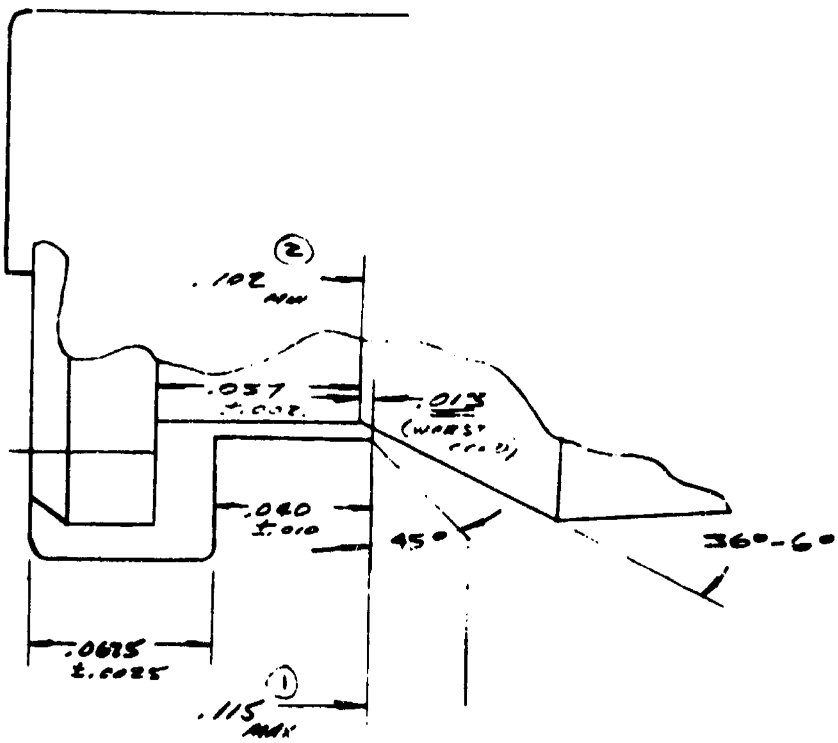
.237 RADII
.172 Δ
.063
.030 HOLD AT NOSE
.033 MIN CLEARANCE W/ [illegible]

064-0000 (0-00)

TECHNICAL ANALYSIS FORM

BY R J HEBERT CK. DATE 2/10/69 REV.	GENERAL ELECTRIC	PAGE 42/44 MODEL REPORT "MINI"

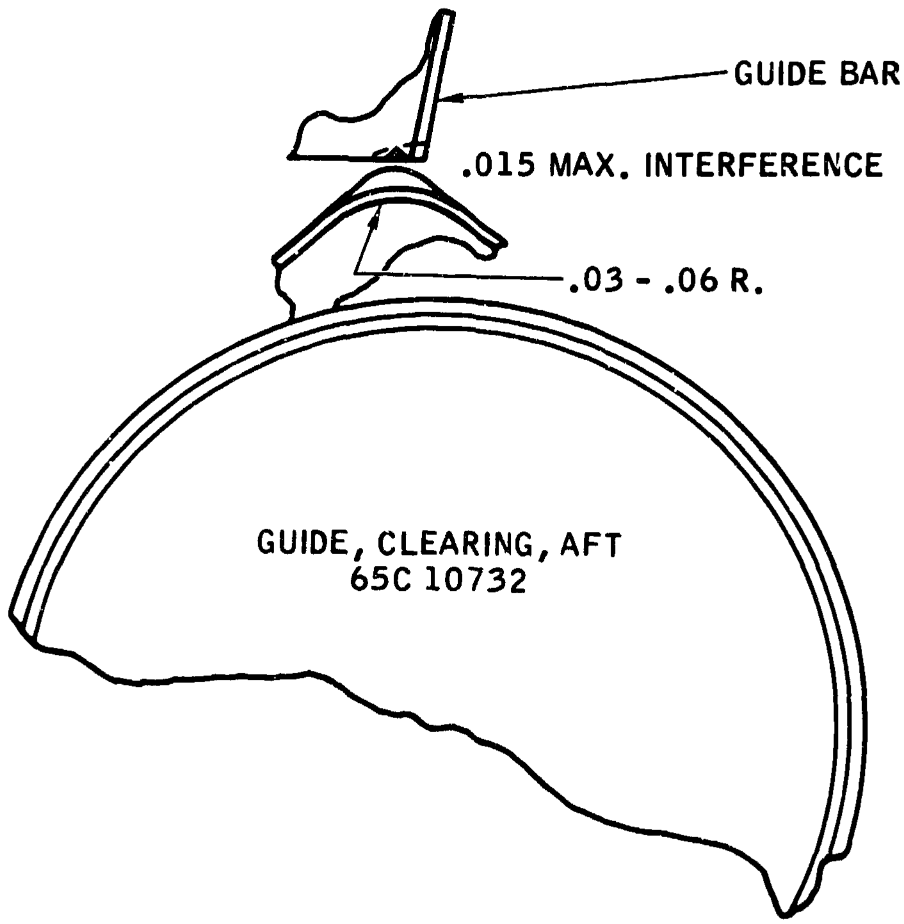
CARTRIDGE CLEARANCE W/ RIM GUIDE



.0625 ±.0025 GROOVE
.0400 ±.0100 FLANGE
.1025 ±.0125 TO START OF 45°
.0125
.115 MAX
.102 MIN
.013 POSSIBLE "HANG-UP"
(STILL IS FREE HOWEVER DUE TO CARTRIDGE CLEARANCE IN GUIDE BAR)

.0505 ±.0035 CART. FLANGE
.0570 ±.0020 GROOVE CART.
.1075 ±.0055 TO START OF 36°
.0055 (−) MIN
.102 MIN.

GEA-### (10-6?)



RESULT: RECOMMEND .05 .02 R. TO CLEAR

Figure 107. Clearing Guide Interference

TECHNICAL ANALYSIS FORM

BY RJ HEBERT CK. DATE 3/31/69 REV.	GENERAL ELECTRIC	PAGE 44/46 MODEL FEEDERS REPORT 'MINI'

MOVEMENT OF FEEDERS AWAY FROM GUN WHEN LOAD

MOD XM & A-37 FEEDER (REFERENCE STUDY PAGES 8 (9))

FEEDER

ASSY - AFT PIN (CLOSEST TO GEARS) = .0035/.0060 LOOSE

FEEDER BRG BORE .5000/.4997 SHAFT .4995/.4985 = .0002/.0015 LOOSE

BRG O.D. 1.1250/1.125 HOUSING 1.1250/1.1266 = .0000/.0016 LOOSE

MOVEMENT OF FEEDER SHAFT .0037/.0089 (INCLUDING PIN)

GUN

BEARING ROTOR BORE 1.3685/1.3680 ROTOR 1.3675/1.3670 = .0005/.0015 LOOSE

BEARING HOUSING O.D. 3.1436/3.1431 HOUSING 3.1516/3.1436 = .0000/.0085 LOOSE

.0005/.0040

MOVEMENT OF FEEDER = .0037/.0089

GUN .0005/.0040

.0042/.0129

POD FEEDER (REFERENCE STUDY PAGE 13)

ASSY = AFT PIN (CLOSEST TO GEARS) = .0035/.006 LOOSE

FEEDER BRG BORE .3752/.3748 SHAFT .3749/.3745 = .0001 TIGHT/.0007 LOOSE

BRG O.D. .6250/.6246 HOUSING .6260/.6250 = .0000/.0014 LOOSE

.0034/.0081 (INCLUDING PINS)

MOVEMENT OF FEEDER = .0034/.0081

.0005/.0040

.0039/.0121

DELINKING FEEDER (REFERENCE STUDY PAGES 21/22)

FEEDER

ASSY = AFT PIN (CLOSEST TO GEARS) = .0035/.006 LOOSE

FEEDER = BEARING BORE .502/.501 SHAFT .4995/.4990 = .0015/.003 LOOSE

BEARING O.D. .627/.626 HOUSING .6255/.6245 = .0005/.0025 LOOSE

MOVEMENT OF FEEDER SHAFT = .0055/.0105

GUN = .0005/.0040

.0060/.0145

SUMMARY

MOVEMENT OF FEEDER FIXED GUIDES (MIN/MAX ...)

MOD/A 37 = .0042/.0129

POD = .0039/.0121

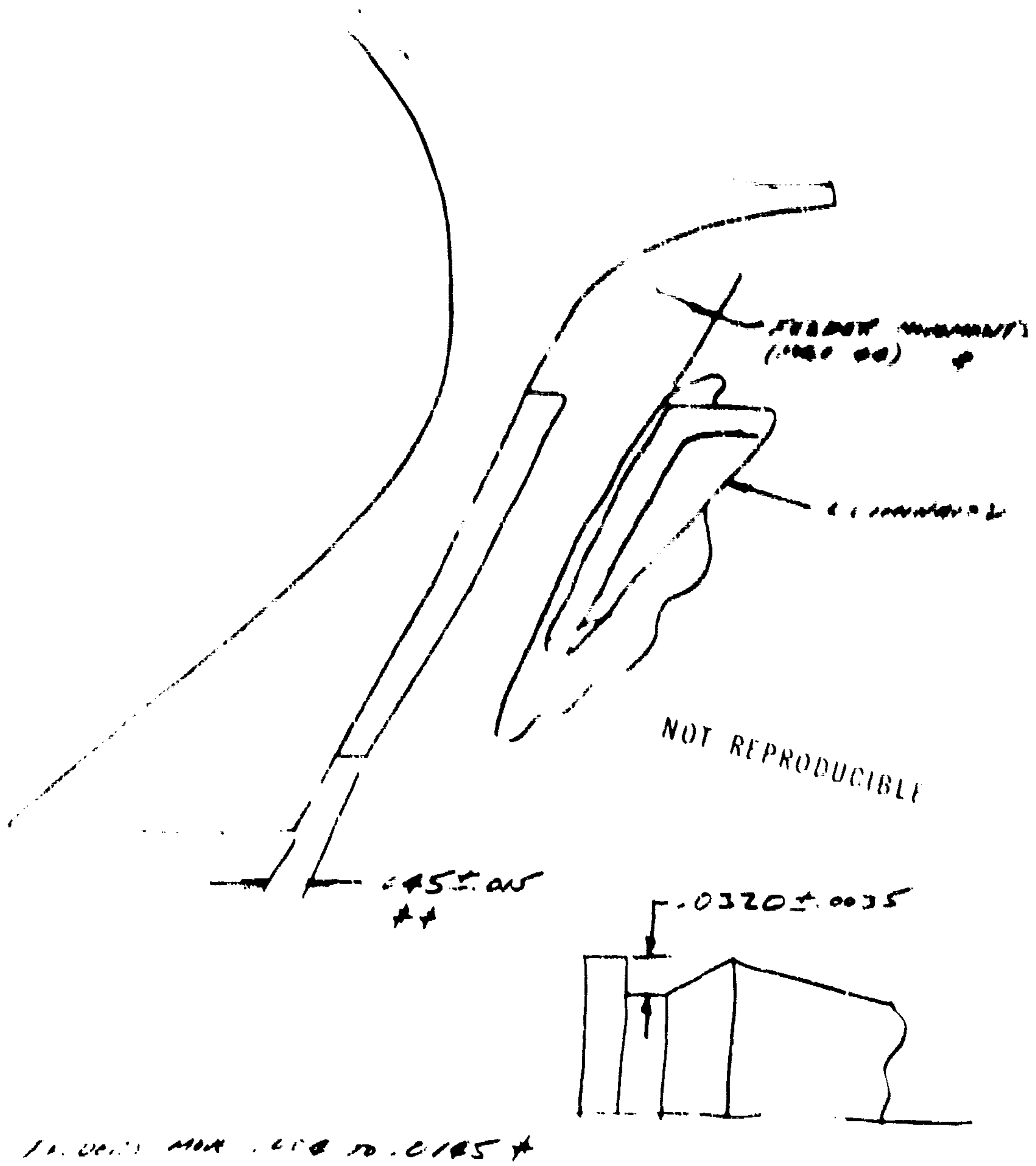
DELINKING .0060/.0145

024-000 (8-50)

TECHNICAL ANALYSIS FORM

BY [illegible]	GENERAL ELECTRIC	PAGE [illegible]
CK		MODEL [illegible]
DATE [illegible] REV		REPORT [illegible]

[illegible]



[illegible] MAX [illegible] TO .0185 #

[illegible] KEY WOULD BE .030 [illegible]

[illegible]

.030 MIN KEY ##

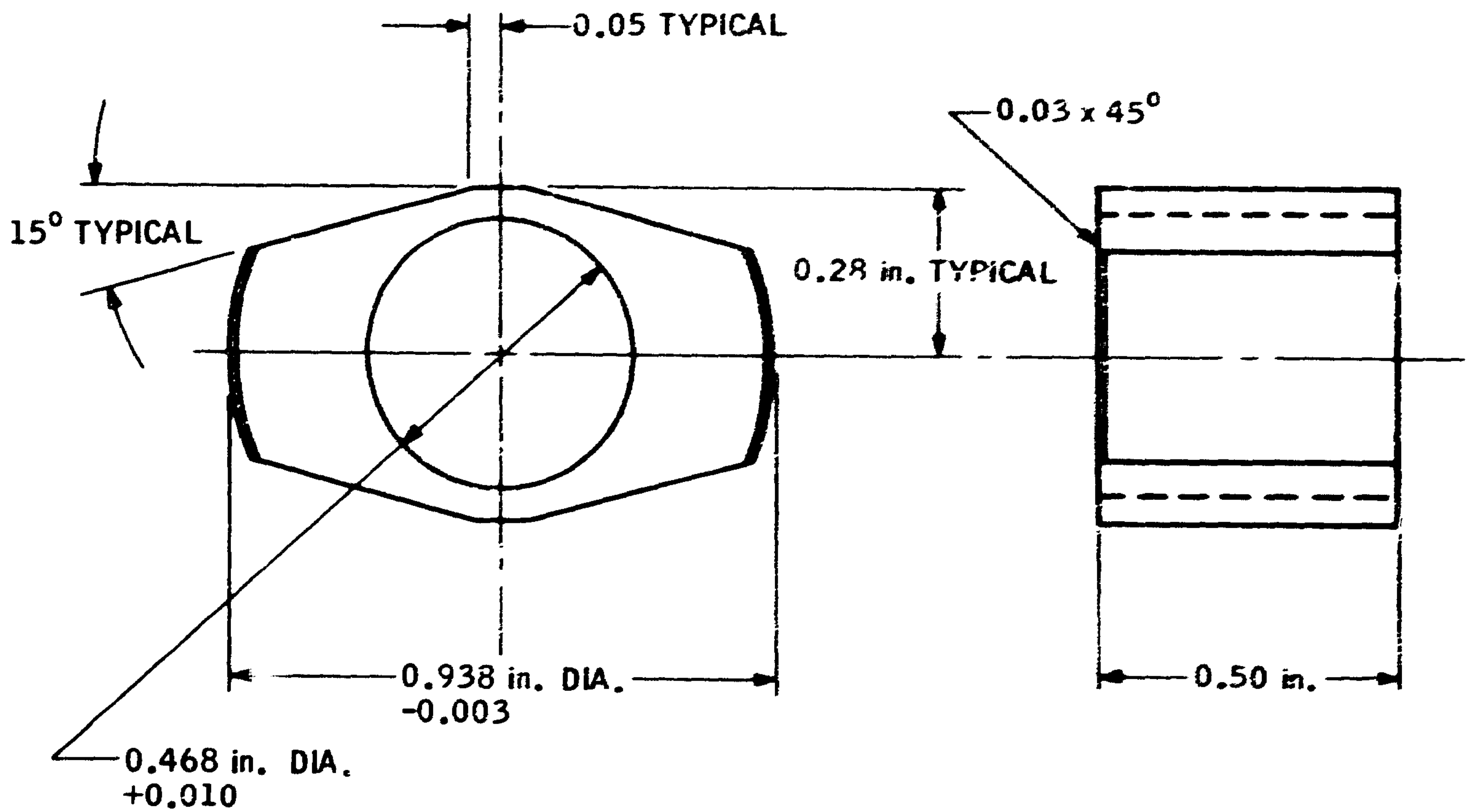
.0185 MAX MOVEMENT OF [illegible]

.0155 MIN [illegible] OF KEY

684-000 [illegible]

Table XII. Summary of Results for High-Speed Films of 7.62-mm Round Handoff

System	Burst	Date Filmed	Frames/sec.	Rate Approx. (spm)	Comments	Observations
A-37	1	1/9/69	3200	2000		Early feed, forward guide bar finger deflects, feeder fixed guides move, feeder sprocket pushes round against guide bar, full seating of round occurs after round has passed over tip of guide bar finger. Guide bar finger deflection is greater for bursts 3 and 4.
A-37	2	1/9/69	3200	4000		
A-37	3	1/9/69	5000	6000		
A-37	4	1/9/69	5000	6000	Jam	
A-37	5	1/9/69	5000	6000		
Pod	1	1/20/69	3200	6000		Observations appear to be the same as the A-37 system.
Delinking Feeder	1	1/23/69	3200	2000		Early feed, guide bar forward fingers deflect same amount, feeder sprocket presses round against feeder fixed guides, round bounces along fingers, round does not follow guide bar profile, guide bar finger deflection more prevalent for bursts 2 and 3.
Delinking Feeder	2	1/23/69	3200	4000		
Delinking Feeder	3	1/23/69	3200	4000		
Delinking Feeder	4	1/23/69	3200	2000		
Module	1	12/19/68	2000	3000		Observations appear to be the same as the A-37 system.
Module	2	12/20/68	3000	6000	Jam	
Module	3	12/20/68	3000	6000	Jam	



BARREL PLUG
MATERIAL: PLEXIGLAS

Figure 108. Barrel Plug

SECTION V

ARMAMENT POD, XM-18, SCOPE ITEM 5

A. INTRODUCTION

When the design and development of the new feed and storage system for the minigun pod was initiated, objectives were established to make the linkless system more reliable, easier to operate and maintain, and more economical to produce. The approach taken to improve the existing system was to decrease the number of moving and fixed parts while simplifying the fabrication of the pod's components. The objectives established to improve the pod system were as follows:

1. Use steel investment castings to replace the aluminum castings on the feeder and exit unit, to eliminate the necessity for separate guides and wear plates and reduce the machining requirements.

2. Eliminate the sheet metal conveyor guide and crossover guide on the feeder to increase reliability, durability, and ease of installation.

3. Include a timed clear , mechanism in the feeder to eliminate clearing jams.

4. Eliminate the drum ring gear, geared retainer partition, and scoop disc assembly by using a single lead sheet metal helix similar in design and function to the MXU-470/A Minigun Module.

5. Incorporate a power load feature to decrease load time and increase ease of operation.

B. SUMMARY

The efforts of this Research and Development program have resulted in a new design that meets and surpasses the target levels of reliability and cost savings established at the beginning of the program. The proven reliability of the minigun module drum has been combined with a new feeder that fired over 200,000 rounds without being responsible for a single stoppage. This combination makes possible a pod system that will easily exceed 100,000 mean rounds between failures. The new feeder, which is interchangeable with the feeder used on all production minigun pods, weighs approximately 1 3/4 pounds more than the unit it replaces. The weight difference is due to the use of steel castings where aluminum was employed. However, the added weight is a small price for the tremendous increase in performance. The new system has many fewer parts and is, therefore, much easier to assemble and maintain - which is extremely important when related to down time in a combat area.

C. DESIGN DEVELOPMENT

Pursuing those objectives established to improve the pod, the design phase moved through layouts to Class I drawings. The ammunition storage area, see Figure 114, incorporates a design similar to the MXU-470/A Minigun Module, which has a rotating finned inner drum and a stationary outer drum helix. The new design eliminates the expensive honeycomb outer structure and replaces it with the forged support, part number 11839419. Loads are transmitted from the suspension lugs through the support and into the drum cover and aft bearing support at each end of the storage drum. This design also eliminates the scoop disc assembly, drum ring gear, and geared retainer. The number of moving parts is reduced from 17 - for the scoop disc assembly, geared retainer, and inner drum of the old pod - to one for the inner drum of the new pod. With fewer moving parts, costs and wear are reduced and reliability is increased.

The inner drum design deviates from the module configuration in that the round space is not radial to the centerline of the drum (see Figures 123 and 124). The round space is canted so that when the drum is rotating in the firing direction the round is held radial to the drum and the base is not permitted to lag. Holding the round radial reduces the friction force on the base of the round and reduces the driving torque required for the drum.

The new exit unit utilizes a precision steel investment casting for its housing, which eliminates the need for four separately attached guides and wear plates. The configuration of the exit unit has been changed from the old design to allow relocation of the loader. The new loader feeds the stripped rounds into the exit sprocket (see Figure 125), rather than into the gear sprocket as in the old design. An intermittent Geneva-type drive was required between the old loader and exit unit for the rounds to be picked up by the exit gear. By moving the pickup point to the exit sprocket, the intermittent drive is no longer needed, which causes a smoother operating assembly.

When dry cycling of the pod system was initially attempted, rounds jammed in the handoff from the inner drum to the exit sprocket. To determine the cause of the poor handoff, a detailed layout similar to Figures 126 and 127 was drawn. Two problems were apparent when the round path was established. First, the timing of the sprocket was such that in the firing direction the sprocket could cram the round, under some tolerance conditions, into the inner drum fin ahead of the round before the round was far enough up the 11839363 guide to be clear of the drum. This condition was experienced with the prototype. Secondly, as the round moved from the drum into the sprocket, round control was minimal. The sprocket did not pick up the round before the centerline of the nose had passed the end of the drum. As the round continued out, the effective working diameter on the nose became smaller. Therefore the drum allowed the base of the round to lag, making pick up by the sprocket impossible.

Two modifications were made to correct the handoff problem. First, the inner drum fins were moved 0.060 inch closer to the sprocket, which gave the drum control of the round for a greater distance up the 11839363 guide. The second modification involved enlarging the retarding the nose round space of the exit sprocket to accommodate the difference in velocity of the nose and base of the round as it moves into the sprocket. With these changes incorporated, dry cycling was successful using rates of 2000 and 4000 spm.

While loading for the first fire tests of the new feed and storage system, approximately one out of every 100 rounds hung up between the loader and exit unit. A design study of this area revealed a possible interference between the loading guide, the round, and the inner round guide (see Figure 125). The guide surface of the inner round guide was lengthened 0.260 inch and moved 0.023 inch away from the round to provide a smoother transition from the loader to the exit unit and prevent any possible interference. The loader and exit unit functioned as desired when the modified parts were installed.

The new loader and exit unit have been designed so the loader is always attached to the exit unit (see Figures 119 and 120). In storage, the loader is held in place against the front of the drum cover by a quick release pin. To load the pod, the quick release pin is removed and the loader is swung into position and secured by the same pin. Having the loader attached to the exit unit in this manner cuts the time required for loading the system.

The primary engineering goals for the redesign of the feeder assembly were that it be interchangeable with the MAU-57A/A production design which is used on all minipods and that the troublesome features that exist in the old feeder be eliminated. These goals have been achieved in the new design (see Figures 111 and 121). The sheet metal conveyor guide, the crossover guide, the 63D10900 and 63C10904 guides, as well as all wear plates, have been eliminated by the use of steel investment castings. See Table XIII for a list of those parts eliminated.

The functions of conveyor guide and crossover guides are now being performed by features incorporated in the feeder housing and sliding wheel support castings. After it leaves the exit unit, the round is controlled by the sliding wheel support base and nose guides for about 70 degrees rotation of the conveyor wheel. The nose guide is an integral part of the sliding wheel support casting. At approximately 12 o'clock, nose control is transferred to the feeder housing. The nose guide then rotates the base of the round down under the base guide of the feeder housing. This action eliminates the function of the scoop guide. The outer guide and clearing jams have been eliminated by a timed clearing mechanism which is similar in principle to those used on other minigun feed systems. This design has produced a unit that has fewer parts, is extremely reliable, easier to maintain, longer lived, and less costly to manufacture.

The rounds counter drive assembly, part number 11839429 (see Figure 109), has been relocated to provide more direct routing for the flexible drive shaft. The assembly is now mounted on the drum cover nearly in line with the counter. This will greatly increase the life of the flexible shaft.

The new pod is provided with redesigned slides to support the battery and control assembly. The stationary portions of the slides are machines from an extrusion and riveted to the aft drum structure (see Figure 115).

The male portions of the slides are mounted to the support assembly frame of the control package. For ease of operation, the mating surfaces of the male and female slides are treated with a dry film lubricant. A latch similar to that used on the old pod is used to secure the control assembly in the pod. The material used for the strike or hook has been changed from aluminum to steel to prevent yielding under high "g" loadings.

A power load capability has been developed for the new pod design. A small motor and gearbox is used to drive the drum, exit unit, and loader when the feeder is disconnected for loading. This motor would be mounted on the aft bearing support in the aft drum, which would require lengthening the aft drum four inches if the present control pack configuration were maintained. Engineering feels the added weight, length, and expense are not justified for the 1500-round pod. However, a new control pack configuration could be developed to reduce the length increase and provide power load capability for a larger capacity pod. A pod capacity of up to 3000 rounds could be developed. The design of the new pod assembly is tailored to adapt to an increased storage capacity by replacing the outer drum and helix assembly, the rotating inner drum, and a power cable adapter.

Table XIII. Parts Eliminated from Feeder

	Part No.	Part
1.	63E10829	Conveyor Guide
2.	63D10843	Crossover Guide
3.	63D10900	Scoop Guide
4.	63C10903	Rim Guide
5.	63C10904	Outer Guide
6.	63C10907	Nose Guide
7.	63D10916	Solenoid Bracket
8.	63D10917	Chute
9.	63C10920	Guide Plate
10.	32 Pieces Miscellaneous Hardware	

D. END ITEM CONFIGURATION

To save large tooling expenses, the prototype pod deviates from the drawing in several areas. All components that form a part of the new design and are delineated as castings, forgings, or extrusions were fabricated from hogouts and/or weldments. One exception is the inner drum extrusion for which a die was built.

While the prototype pod was being built and tested, several changes were made in the drawings which would have required welding to bring the parts to the new configuration. These changes were not critical to the function of the assembly; therefore, to avoid possible warpage of the parts by welding, the following items are not to the latest drawing revision:

1. The holes for two MS35207-264 screws (see Figure 110) which secure the inner guide, part number 11839304, to the exit unit housing were located so that under some tolerance conditions the nuts could interfere with the exit gear sprocket, part number 11839319. The drawing was changed, but because there was no interference on the prototype unit the parts were not changed.

2. The timing pin, part number 11839397, Figure 114, was mislocated on the design layout. If the pin in the exit unit and the pin in the drum cover are depressed as the exit unit is placed on the drum cover, timing will be correct. However, after the exit unit is secured with hardware, both pins cannot be engaged simultaneously. A simple check by running a round through the exit unit and into the drum will insure proper timing has been obtained.

3. Figure 121 shows a guide at the left of the solenoid that is mounted to the feeder housing by one screw. On the drawings this guide is not a separately attached part, but is cast as an integral part of the housing.

E. TESTING

The feeder was the first assembly of the new pod to be completed. Because it is interchangeable with the old pod design, it was mounted on an XM-18E1 pod and successfully fire tested. High-speed films were taken to study the movement of the rounds through the feeder. The transition of the round from the sliding wheel support to the feeder was very smooth, and round control was maintained at all times. Final design configuration was established after the first two complements. In final form, 52,000 rounds were fired with the feeder on an XM-18E1 pod. During this testing only three stoppages occurred, and these were caused by bent rounds which were caused by a faulty scoop disc assembly. There were no feeder stoppages or malfunctions.

Additional testing of the feeder began when the prototype storage drum and exit unit were completed; 150,000 rounds were fired with the feeder on the new pod. The feeder performed flawlessly throughout this test with no stoppages or malfunctions.

The 150,000-round engineering test was conducted on the prototype feed and storage system to prove the design and establish the system's reliability. See Appendix V-C for summary test results. Rates fired were from 2000 to 6000 spm, utilizing both Air Force and Army gun drives. Burst lengths were varied from 50 to 300 shots.

After firing the first two complements, design changes were made in the loader and exit unit as explained in Section IV, Part C, "Design Development." Following these changes, the feed and storage system, which was in its final design configuration, successfully fired the remaining 147,000 rounds. Six stoppages occurred, four resulted from hangfires, one was caused by a safing sector pin's coming loose, and the last was caused by a personnel error when loading the system. Thus the new feed and storage system handled 147,000 rounds without being responsible for a single stoppage. It also proved to have a high level of durability as none of the system's primary components was damaged by these stoppages. The only repairs required for the feed and storage system were the replacement of the feeder drive gear pin and the exit gear pin on three of the six stoppages.

The 150,000-round test established that the new pod design has both high reliability and high durability, which combine to save many dollars in repair parts and labor and to keep the system operational for many more missions.

APPENDIX V-A

Drawings

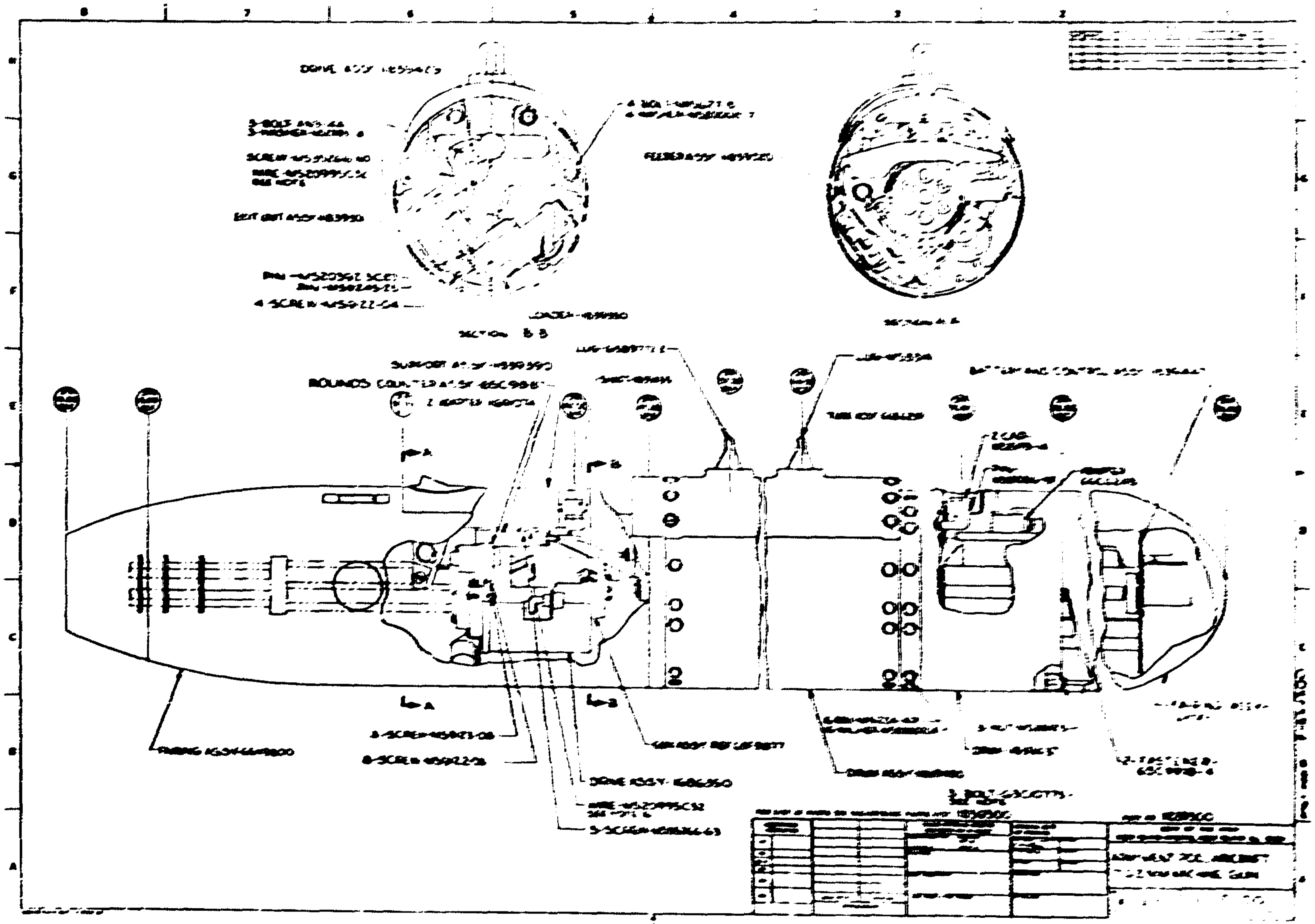


Figure 109. Aircraft Armament Pod

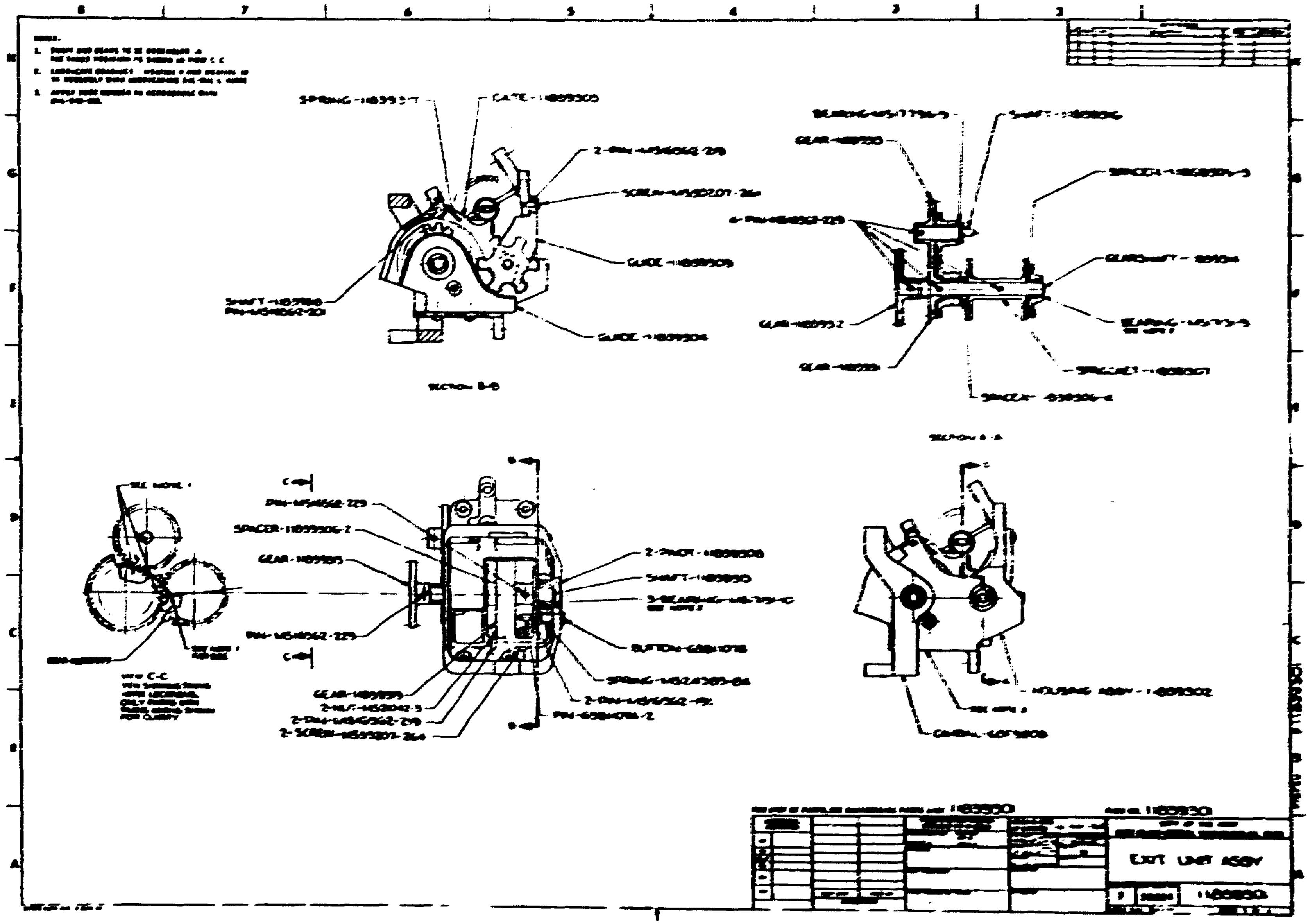


Figure 110. Exit Unit Assembly

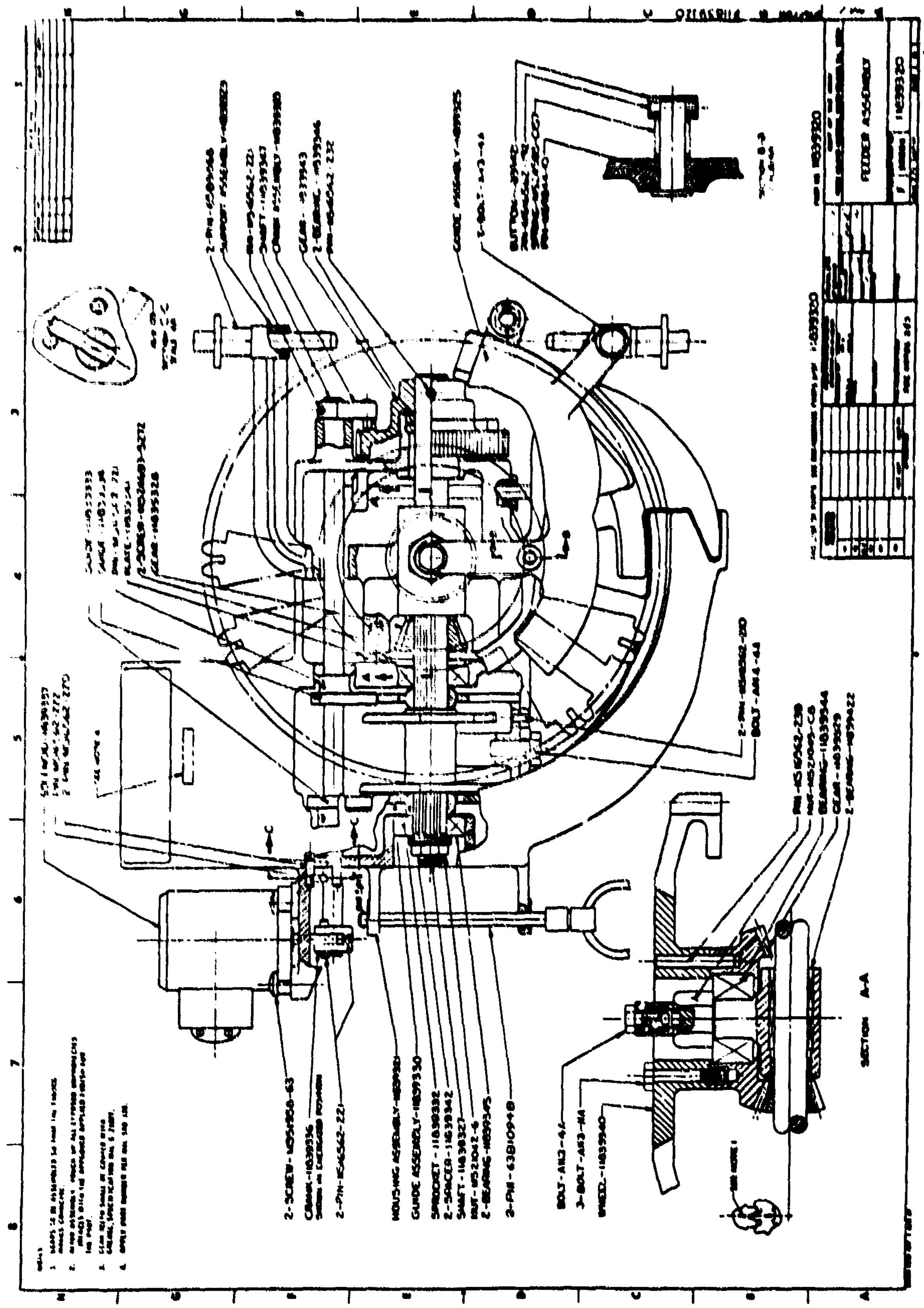


Figure 111. Feeder Assembly

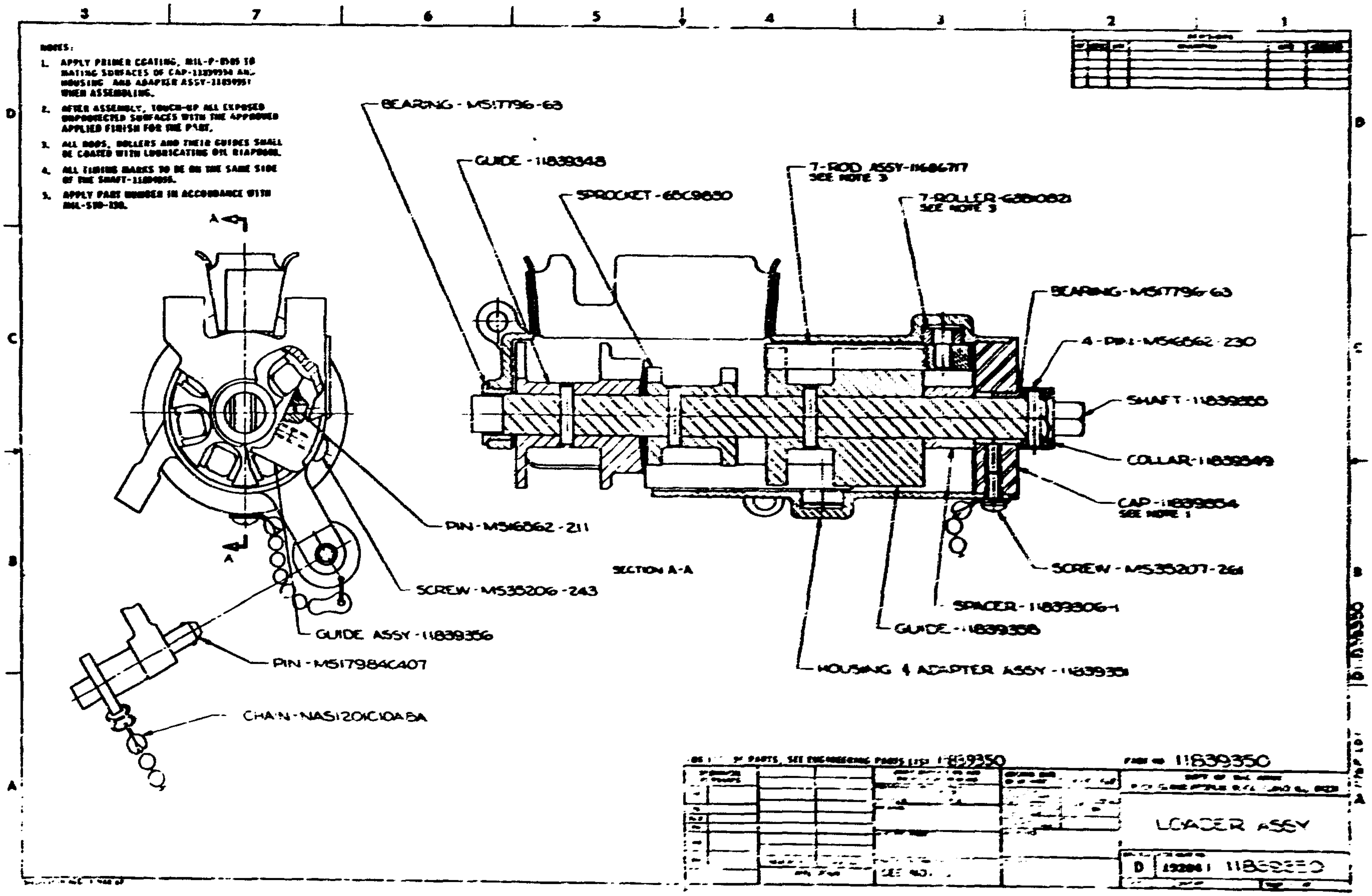


Figure 112. Loader Assembly

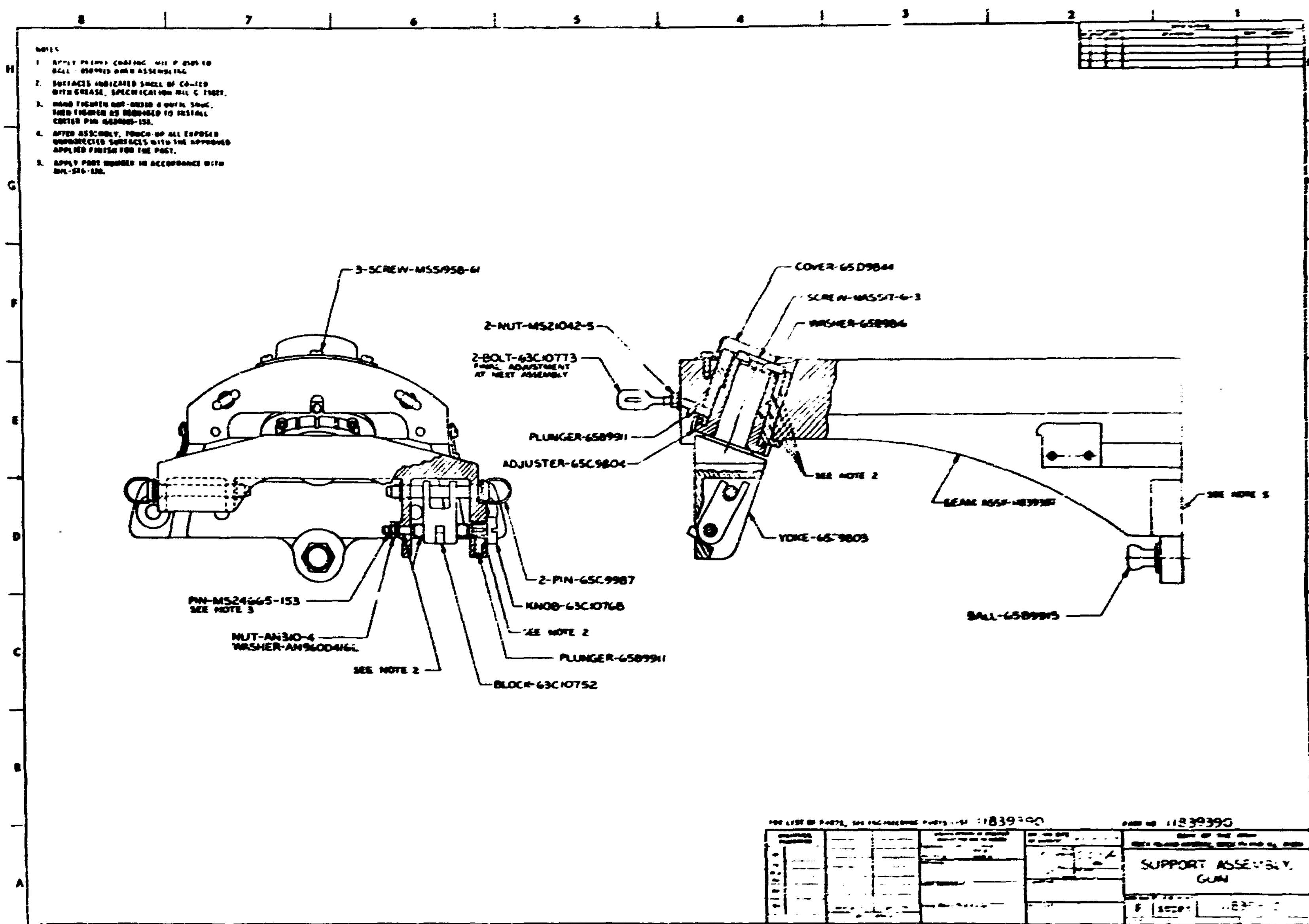


Figure 113. Gun Support Assembly

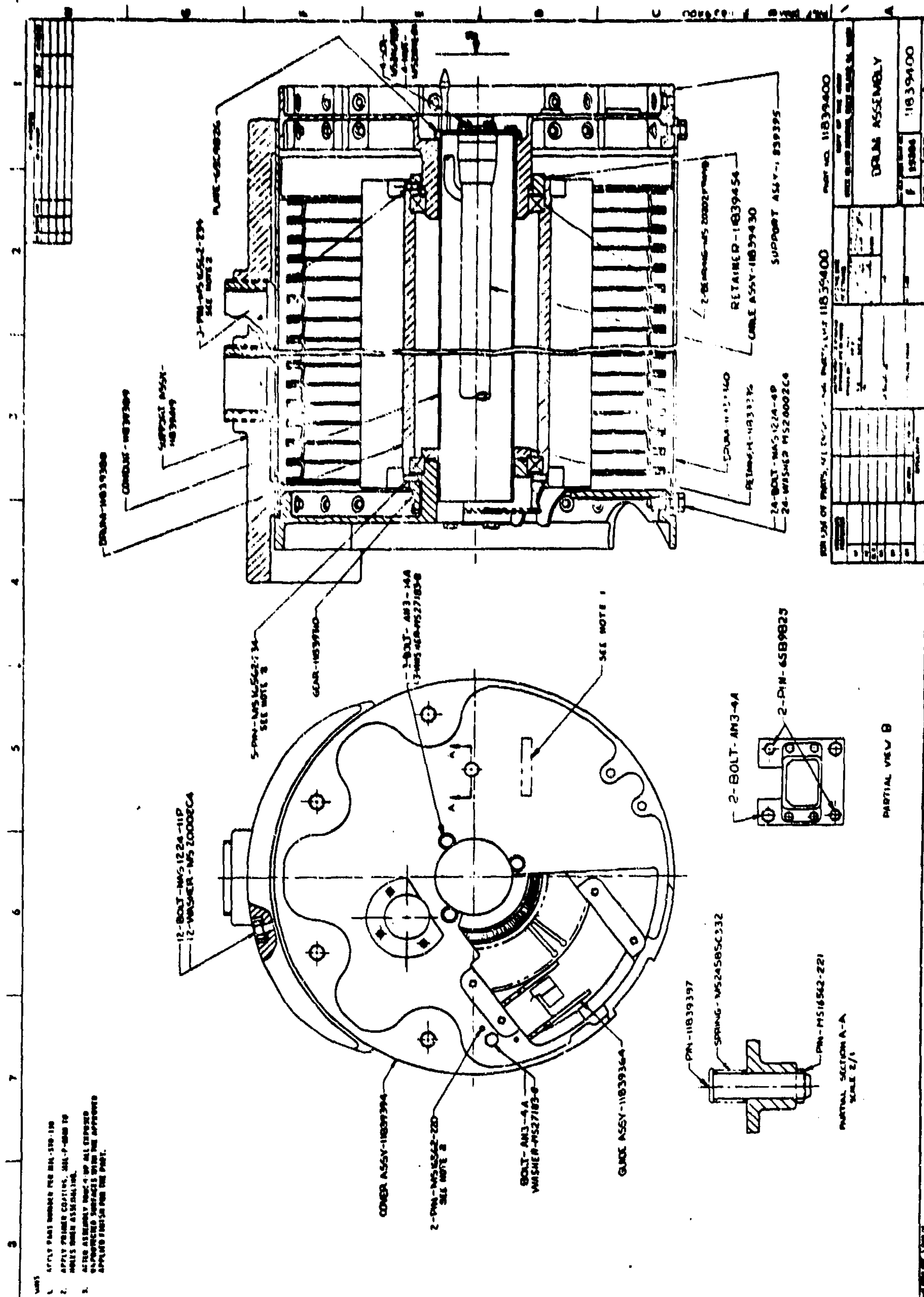


Figure 114. Drum Assembly

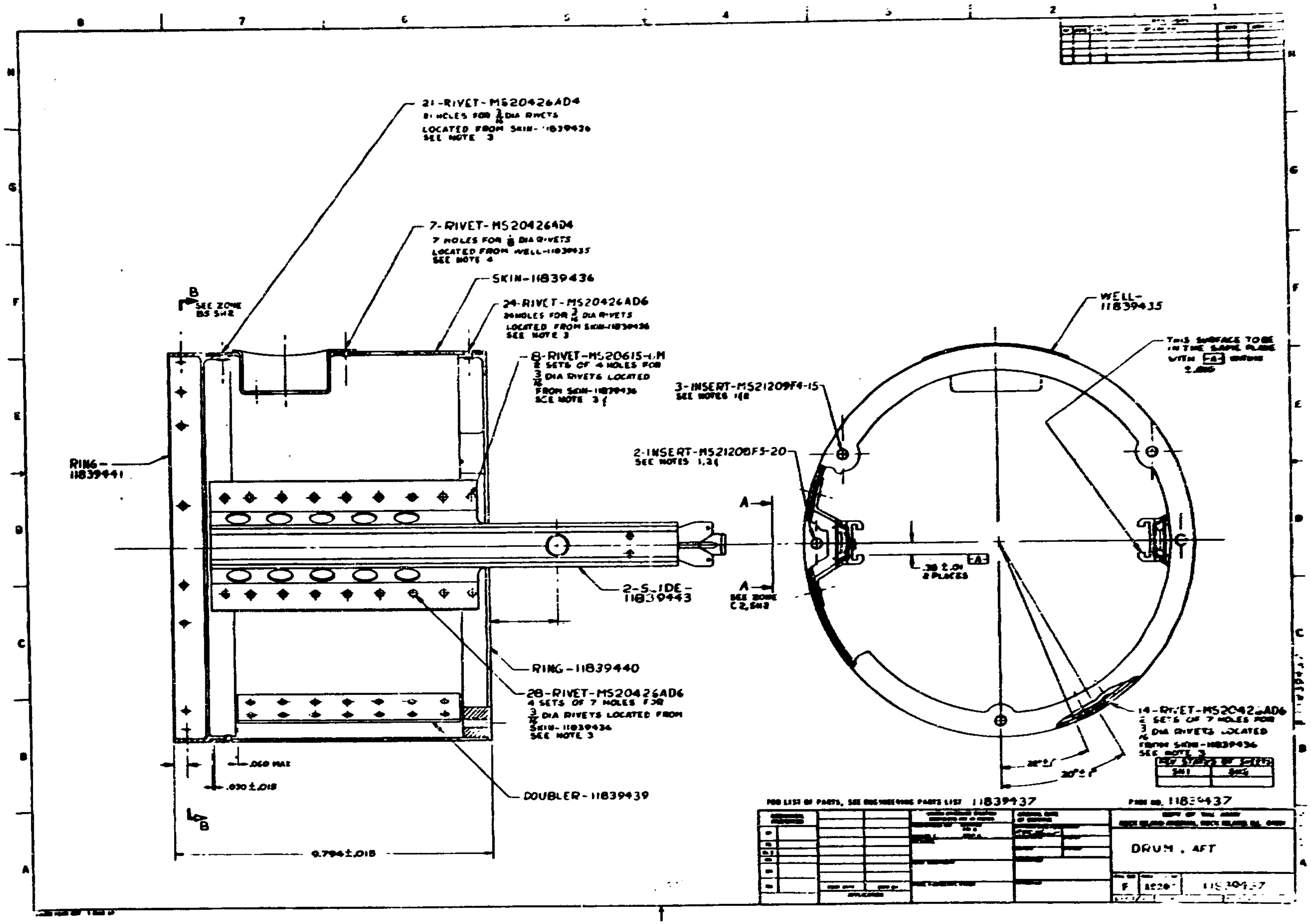


Figure 115. Aft Drum Assembly

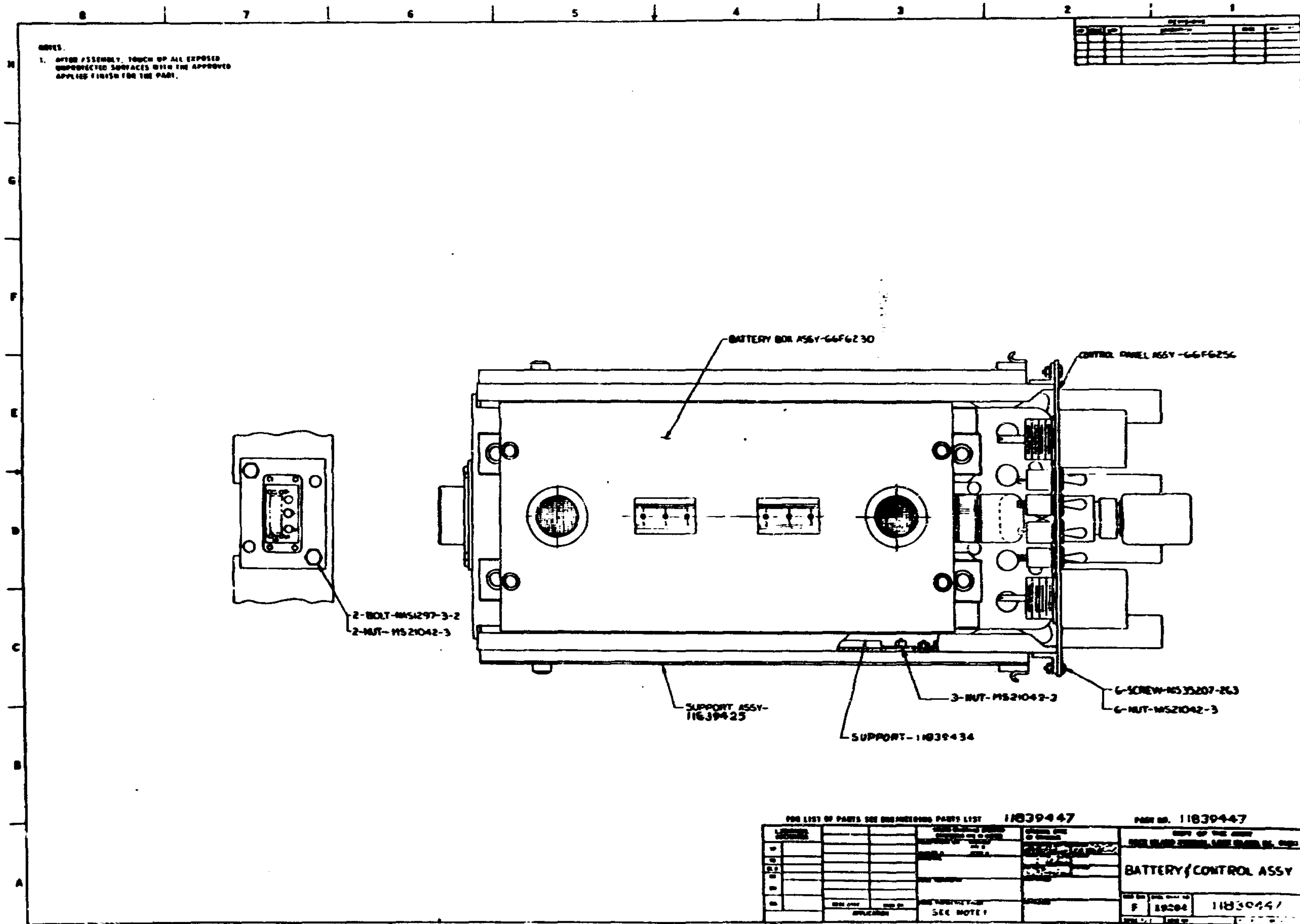


Figure 116. Battery and Control Assembly

A P P E N D I X V-B

Photos and Illustrations

Figure 117. Feed and Storage System with Gun (Right Side View)

Figure 118. Feed and Storage System with Gun (Left Side View)

Figure 119. Loader and Exit Unit with Loader in Load Position

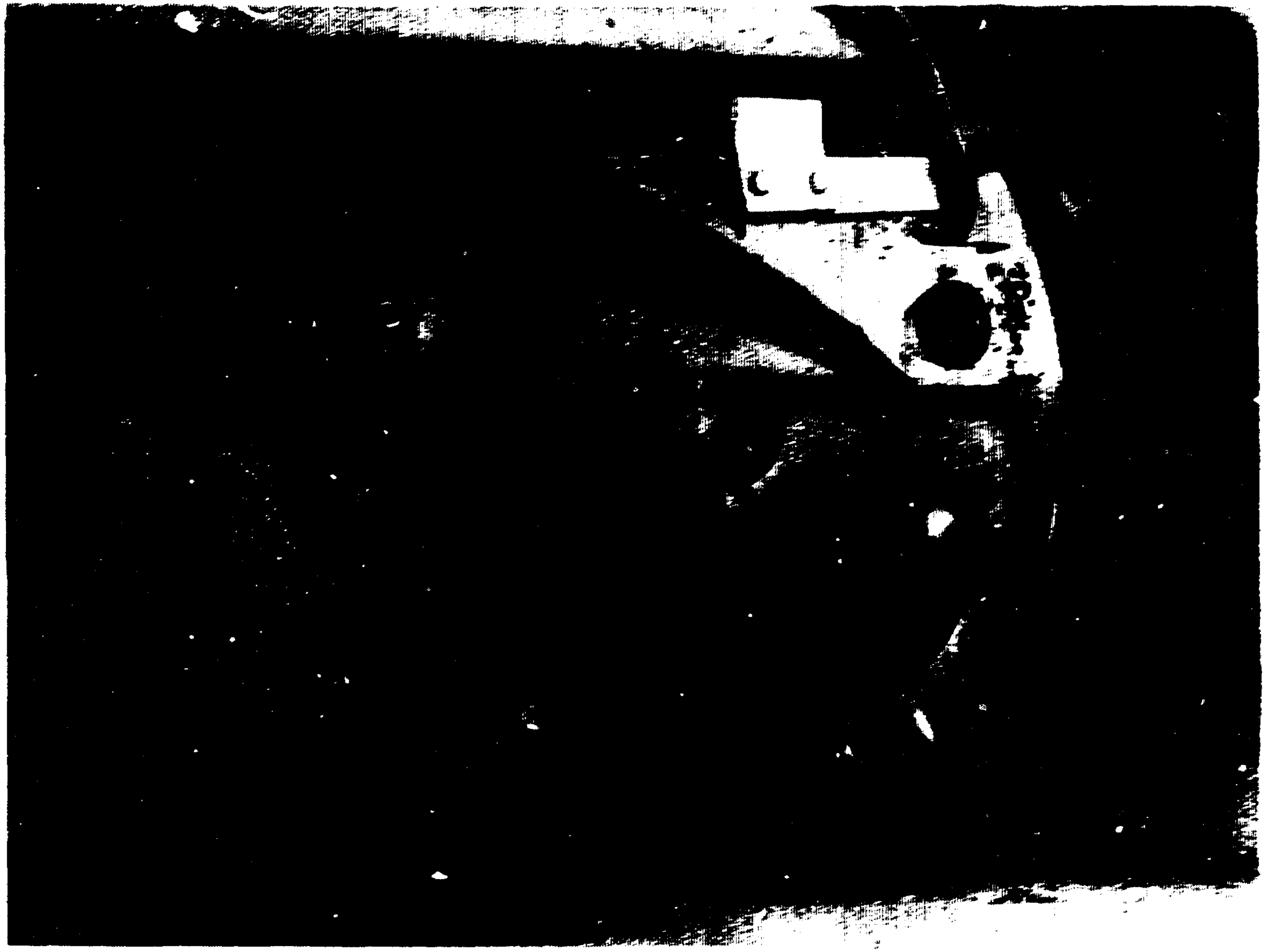


Figure 120. Loader and Exit Unit with Loader in Stored Position

Figure 121. Feeder Installed on Pod

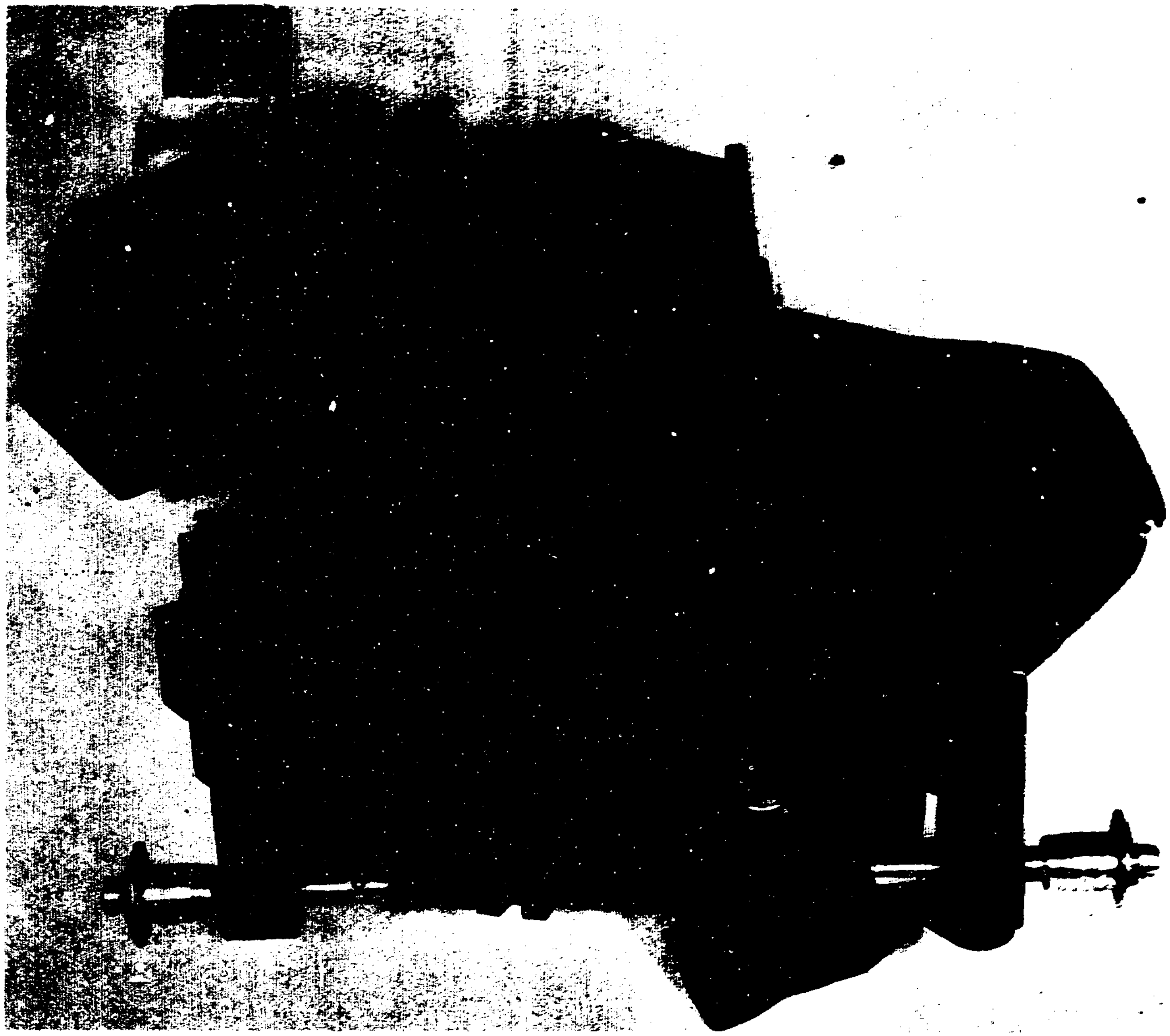


Figure 122. Feeder Showing Timed Clearing Mechanism

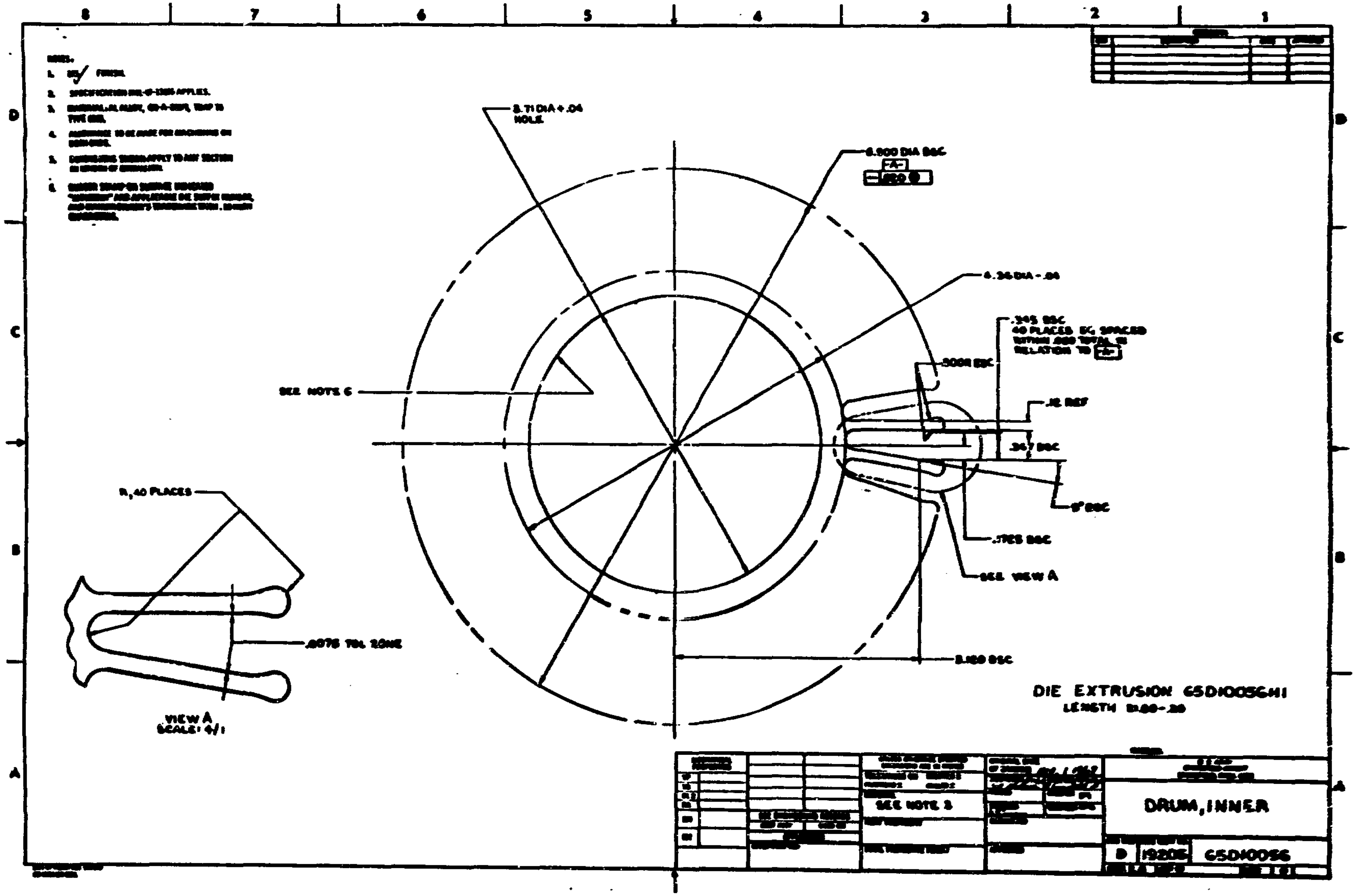


Figure 123. Inner Drum Extrusion

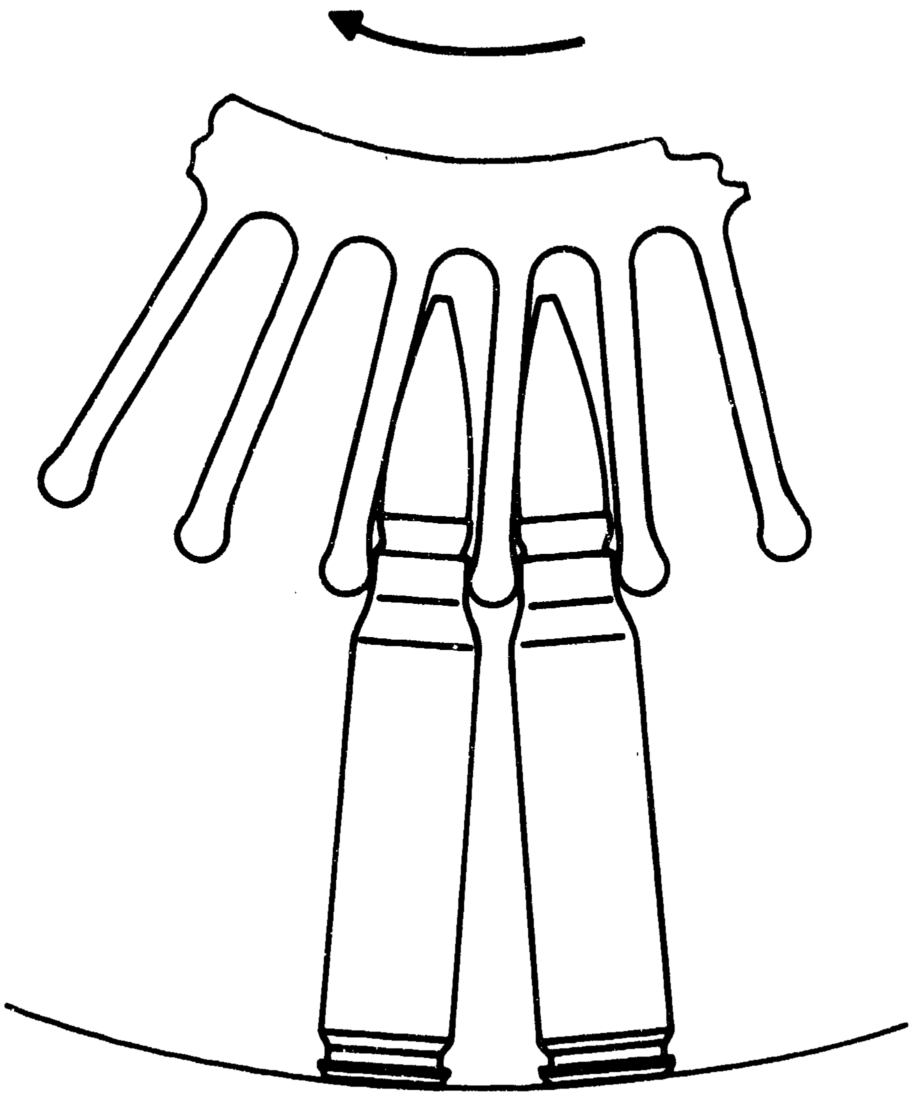


Figure 124. Round Positioned in Inner Drum

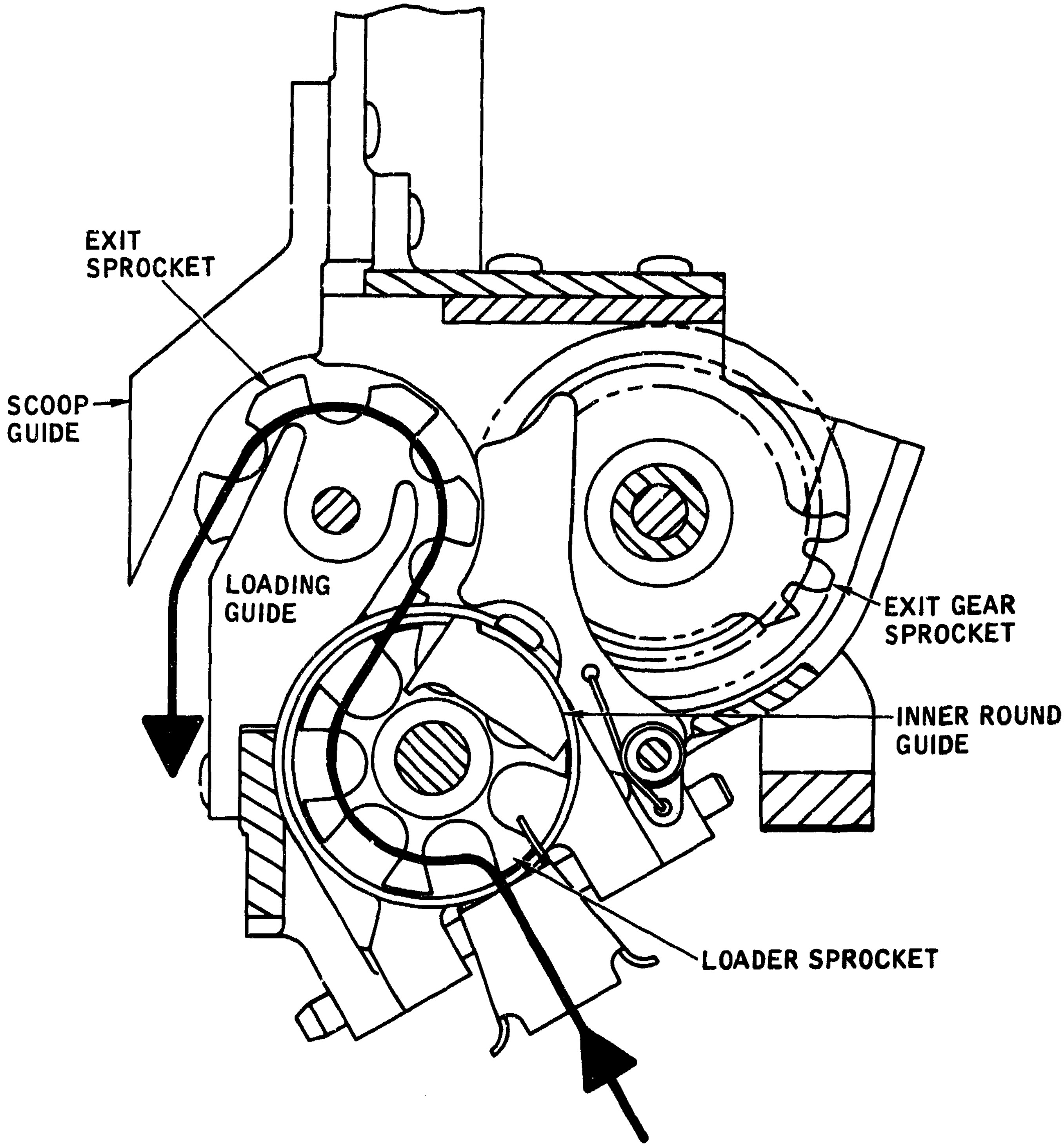


Figure 125. Round Path Through Loader and Exit Unit, New Design

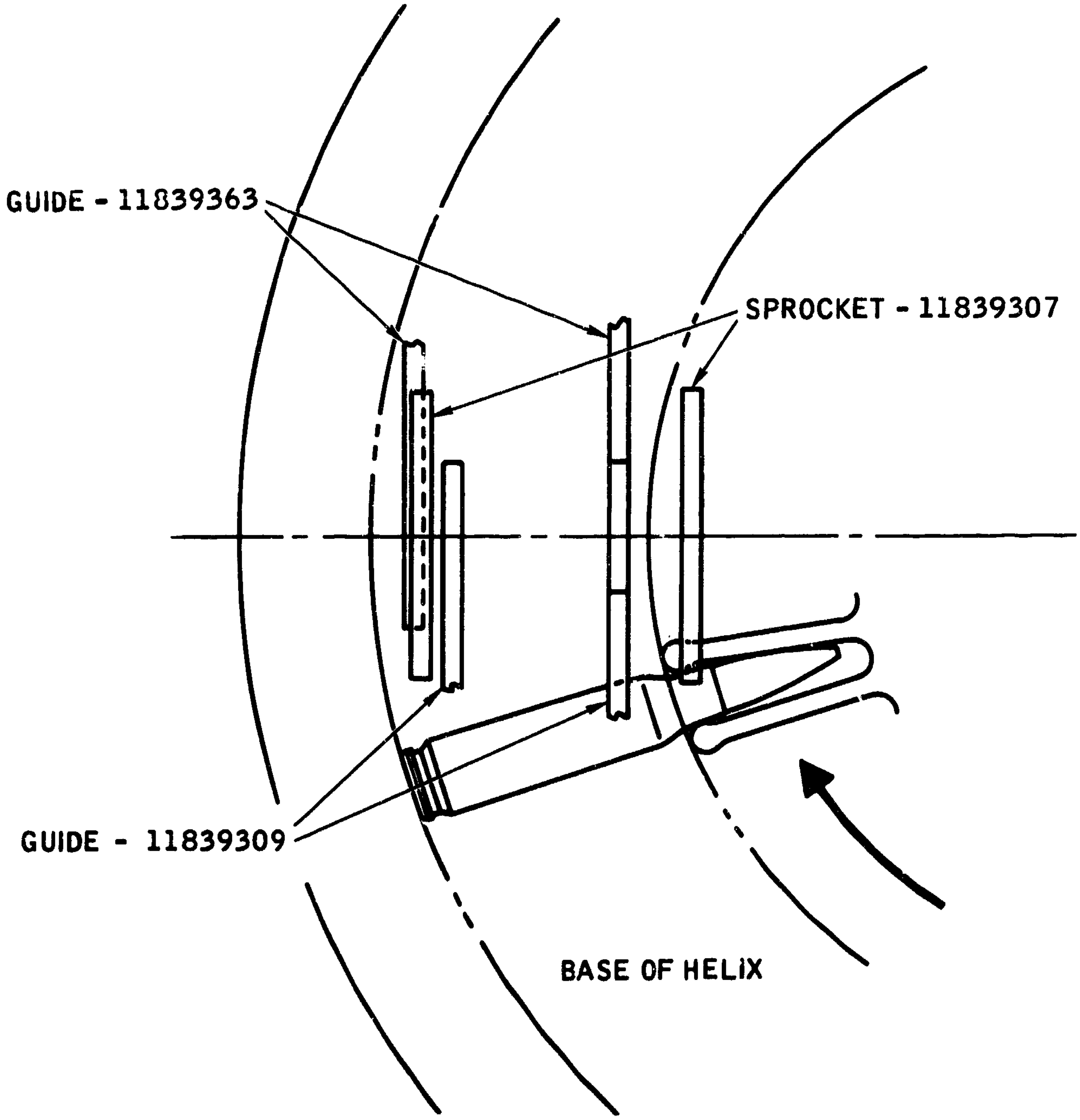


Figure 126. (Sheet 1 of 2) Design Study of Inner Drum to Exit Sprocket Handoff

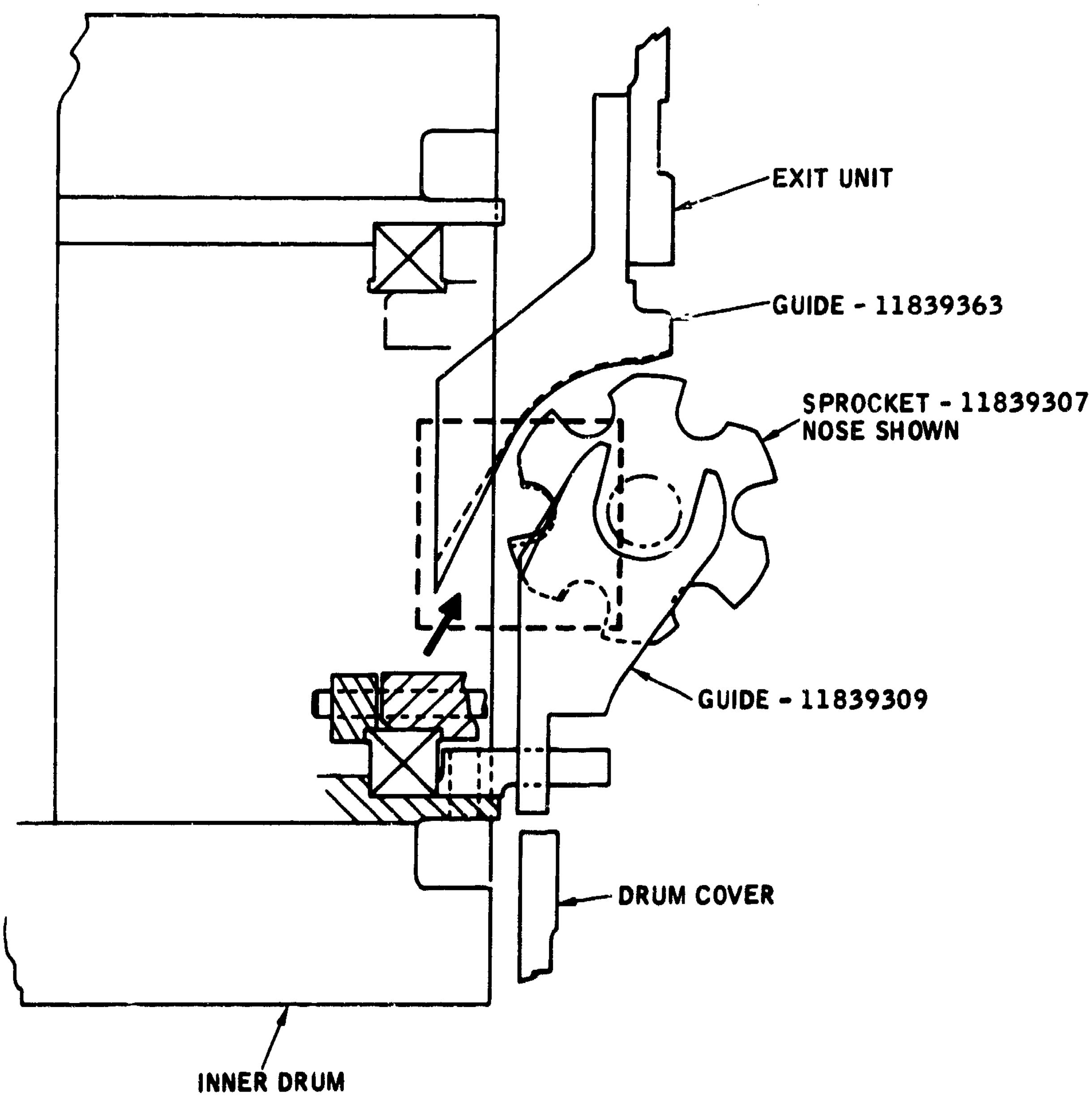


Figure 126. (Sheet 2 of 2) Design Study of Inner Drum to Exit Sprocket Handoff

A P P E N D I X V-C

Test Results

Table XIV. Summary Results on 150,000-Round Engineering Reliability Test of Research and Development Feed and Storage System

Comp. No*	No. of Bursts	Rate (spm)	Status
1	15	2000-4000	No go burst 7 - round damaged during loading jammed at exit sprocket
2	11	3000-6000	Stoppage burst 4 - same as above
	Installed modified loading guide and round guide to eliminate loading damage		
3	8	2000	OK
4	5	4000	OK
5	5	4000	OK
6	5	3000	OK
7	8	6000	OK
8	8	6000	OK
9	5	6000	OK
10	8	6000	Stoppage burst 5 - bent round jammed in feeder - personnel error damaged rounds during loading
11	8	6000	OK
12	8	6000	Hangfire burst 6 - gun stoppage resulted
13	8	6000	OK
14	8	6000	OK - installed Research and Development bolts in gun
15	8	6000	OK
16	8	6000	OK
17	8	3000	OK
18	8	3000	OK
19	5	3000	OK

Table XIV. Summary Results on 150,000-Round Engineering Reliability Test of Research and Development Feed and Storage System (cont.)

Comp. No.	No. of Burst	Rate (spm)	Status
20	5	3000	OK
21	5	3000	OK
22	5	3000	OK
23	5	3000	OK
24	7	3000	OK
25	5	3000	OK
26	5	4000	OK
27	8	4000	OK
28	5	4000	OK
29	5	4000	OK
30	5	4000	OK
31	8	4000	OK
32	5	4000	OK
33	8	4000	OK
34	5	4000	OK
35	8	4000	OK
36	5	4000	OK
37	8	4000	OK
38	8	2000	OK
39	8	2000	OK
40	8	2000	OK
41	5	2000	OK
42	8	2000	OK

Table XIV. Summary Results on 150,000-Round Engineering Reliability Test of Research and Development Feed and Storage System (cont.)

Comp. No.	No. of Bursts	Rate (spm)	Status
43	8	2000	OK
44	8	2000	Stoppage - safing sector pin came loose from gun - damaged (1) Research and Development bolt, guide bar, and roll pins
45	8	4000	OK
46	8	4000	OK
47	8	4000	OK
48	8	4000	OK
49	8	4000	OK
50	8	4000	OK
51	8	2000	OK
52	5	2000	OK
53	8	2000	OK
54	8	2000	OK
55	8	2000	OK
56	8	4000	OK
57	5	4000	OK
58	8	4000	OK
59	5	4000	OK
60	5	4000	OK
61	8	4000	OK
62	5	4000	OK
63	8	4000	OK

Table XIV. Summary Results on 150,000-Round Engineering Reliability Test of Research and Development Feed and Storage System (cont.)

Comp. No.	No. of Bursts	Rate (spm)	Status
64	5	4000	OK
65	6	4000	Hangfire stoppage - no damage to gun or pod
66	8	4000	OK
67	5	4000	OK
68	5	4000	OK
69	8	4000	OK
70	8	4000	OK - Removed Research and Development bolts
71	5	4000	OK - Reinstalled Research and Development bolts
72	6	2000	Hangfire stoppage - no damage
73	8	2000	OK
74	8	4000	OK
75	5	4000	OK
76	5	2000	OK
77	5	2000	OK
78	5	4000	OK
79	6	4000	OK
80	5	4000	OK
81	5	4000	OK
82	5	4000	OK
83	5	4000	OK
84	5	4000	OK

Table XIV. Summary Results on 150,000-Round Engineering Reliability Test of Research and Development Feed and Storage System (cont.)

Comp. No*	No. of Bursts	Rate (spm)	Status
85	5	4000	OK
86	5	4000	OK
87	6	4000	Hangfire stoppage - no damage
88	5	4000	OK
89	5	4000	OK
90	5	4000	OK
91	5	4000	OK
92	5	4000	OK
93	5	4000	OK
94	5	4000	OK
95	5	4000	OK
96	5	4000	OK
97	5	4000	OK
98	5	4000	OK
99	5	4000	OK
100	5	4000	OK

*Each complement is 1500 rounds.

A P P E N D I X   V-D

Weight and Center of Gravity

Table XV. 7.62-mm Aircraft Machine Gun Armament Pod, Weight Data Report

Item	Part Name	Part No.	Wt. Code	Cal. Unit	Wt. Total	No. Req.	Act. Unit	Wt. Total	Roll X	Yaw Z	Pitch Y
									Sta.		
1	Forward Fairing	65K9800						10.70	29.36		
2	Support Assy.	11839390						19.50	38.86		
3	Gun Assy. with Recoil Adapter	65F9877 and 11691074						38.25	33.63		
4	Electric Drive Assy.	11686350						7.40	39.98		
5	Drum Assy. with Lugs	11839400						96.45	59.42		
6	Aft Structure Drum	11839437						7.31	78.82		
7	Battery and Control Assy.	11839447						51.20	81.82		
8	Aft Fairing	11839457						3.82	86.87		
9	Feeder Assy.	11839320						11.75	40.64		
10	Exit Unit Assy.	11839301						5.00	47.00		
11	Loader	11839350						3.50	47.49		
12	1500 Rds. Ammo.				83.14						
	Pod Empty				254.89				56.35		
	Pod Loaded				338.03				57.20		

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Security Classification

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Not Applicable	U. S. Army Weapons Command Rock Island, Illinois

13. ABSTRACT This report describes the design, development, and testing of a new minigun bolt, clutch, sidestripping feeder, guide bar, and armament pod for the XM-18.

The new bolt functions independently of any external cam other than the main housing cam, and is completely interchangeable in all existing systems. Other advantages include reduced cost, longer life, and greater reliability.

The new solenoid operated clutch is in the aft end of the gun and does not interfere with the feed systems of the many minigun applications. The clutch stops the feed system at the end of a burst, but allows the gun to rotate and clear. A large savings is realized because no live ammunition is dumped.

The new delinking feeder sidestrips, rather than endstrips. It has fewer parts, is more durable, and thereby reduces cost and increases feeder life.

Tolerance studies of the guide interfacing with gun and feeder, high-speed films of round handoff, and evaluations of various guide bar concepts were performed to try to design a guide bar which would decrease dependency on feeder timing and increase tolerance to damaged ammunition.

The new feed and storage system for the minigun pod incorporates a storage drum similar to the MXU 470 Minigun Module with a new feeder design that has fewer parts and is more durable. The combination of these two features more than doubles the reliability of the pod.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Self-Actuating Bolt						
2. Tuftrided Pins						
3. Spring Energy						
4. Minigun						
5. Clutch						
6. Clearing						
7. Sidestripping						
8. Feed						
9. Link Ejection						
10. Stripper Sprocket						
11. Minigun Guide Bar						
12. Guide Bar						
13. Round Accelerators						
14. Feeders						
15. Ammunition Feeder						
16. Storage Drum						
17. Minigun Pod						

Security Classification